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GAS JOURNAL

LIGHT • HEAT • POWER • BYE-PRODUCTS

[Founded in 1849 as the "Journal of Gas Lighting."]

VOL. CLXVII. No. 3190] LONDON, JULY 2, 1924. [76TH YEAR. PRICE 2s.

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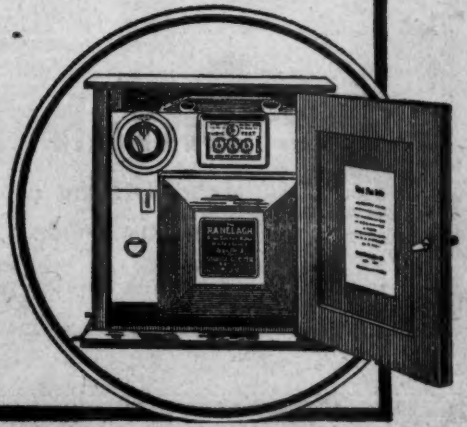

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VOL. CLXVII., No. 3190.] WEDNESDAY, JULY 2, 1924. [76TH YEAR.

EDITORIAL NOTES.

The Meeting of the Institution.

IT was a glorious week. Everything shaped well and went well; and the President (Mr. Samuel Tagg, M.Inst.C.E.) will look back upon these days, which have contributed history to the industry, as constituting one of the most important events in his professional career. His personality had much to do with the success of the meeting. It is one thing to have a great reputation; it is a better thing to have a good reputation, and to be beloved by all men whose regard one cares to have. But, even so, he was fortunate in the closing days of his year of office. There are several things which enable us to say this. We shall not be surprised to learn that the attendance on this occasion was a record one. For this the President's popularity is largely responsible. But there were other influences at work; and this the President, we know, fully realizes. There was Wembley. Everybody wants to see this grand exhibition—the exhibition without compare, the exhibition which, big as it is, merely typifies the power and resources of the British Empire. It is an exhibition of which we are patriotically proud; and many gas men, with their ladies, went out to see it last week. Then there was the invitation to Paris to join in the celebrations of the Centenary of the gas industry there, and conjoined was the Jubilee of the Société Technique du Gaz. Further, the weather was—for a change—in generous mood, and largely helped to promote the happiness and good spirits that prevailed. We could not have wished for anything better. Accompanying all this was the fact that a most convenient meeting centre had been placed free of charge at the disposal of the Institution by the Institution of Electrical Engineers, the Council of which body do not share the views of certain lesser lights of the electrical professional ranks, who think that cemetery accommodation rather than housing accommodation is what ought to be provided for the gas industry.

There are other reasons for the growth in the number of members attending the meeting, and for the sustained interest in the proceedings. The affairs of the industry have changed so much—the demand for the highest efficiency is so great—that there is an insistence upon the acquisition of the latest knowledge. It is imperative to be up to the times; otherwise men, like businesses, must go under. Another noticeable feature is that the higher technical training of the men who are permeating the professional ranks of the industry is making itself felt at the meetings. We see, feel, and know this. The matters presented for consideration, and their discussion, are altogether of a more brilliant order than was at one time the case. Our research experts are also fully aware of this. They realize the presence of the competent critic. Then there are the mutations in policy and in the commercial operations of the industry—all of which impose new responsibility, and necessitate increased application. But the industry is shaping well in all respects with the view of meeting its obligations and of encountering the resistances to an open path of progress. The President's address faithfully presented the facts. Research, as the proceedings at the meeting exemplify, is month by month and year by year bringing to us fresh knowledge, and positive solutions to intricate problems, which are ever on the increase. It is removing the weeds and the brambles from the entrances to fresh channels of development, and directing to the way we must go. The scheme of education and examination which the Institution has framed, with the help of influential and interested collaborators, will do much to raise the standard of efficiency in all the technical quarters of the industry. But as in research, so in the matter of suitable technical training, there is yet much to be done. This was evident from the report of the Advisory Committee, and from the observations of the Chairman (Mr. F. W. Goodenough) in presenting it. A good start has been made; but the experience points to certain things. The interest of administrators of gas undertakings in this matter is not so general as it should be. Where appreciation as to need does not exist, where it is thought that the old order of things is good enough for new conditions, there some activating influence is required to remodel thought and to spur on to action. Given such a change, the supply of students would increase. As things are, too, the need is obvious for a concentration of educational facilities. Technical schools are not prepared to introduce new courses and to make special provision without an adequate supply of students. The only way to meet this is by territorial centralization, so that one centre may serve a district with a radius of (say) 20 miles. In all respects there is much to be done—not only in the matters of research and education, but in others in which the technical man must have part.

Generally speaking, it must be admitted that the administrators of the gas industry are doing well in supporting its co-operative movements; but this important matter of efficient educational facilities with the view to promoting higher standards of efficiency in the technical ranks generally has not taken such hold as we hope to see develop. Linked to this in a way which need not be specifically described in order to make it obvious, is the suggestion that Dr. Carpenter made at the President's luncheon. He urged very earnestly that chief officials of gas undertakings should not regard the occupancy of the Presidential Chair of the Institution as the highest goal of their ambition. In his opinion, it should be looked upon as the intermediate stage. The ultimate reward for the expenditure of energy, the acquisition of knowledge, the sacrifice of time, and the experience gained, should be participation in the administration of gas undertakings, upon which the specialized knowledge could be brought to bear, with a production of advantage which would be impossible with outsiders whose lives are spent in other interests. Dr. Carpenter is confident there will be, and must be, development in this direction, while retaining a leaven of outside knowledge and influence. When this participation in administration of trained men comes about with stronger force than at the present time, we shall see a more general appreciation of those things which are essential to the well-being of the industry in these times of new conditions.

The changed conditions are recognized by Mr. H. C. Honey, the Director of Gas Administration at the Board of Trade. He occupies an exceptionally good position from which to make observation of the doings, developments, and requirements of the industry. He was at the President's luncheon, and made a speech which reflected the excellent relations which exist between his Department and the men of the industry, among whom he has made many friends—not only men associated with the large undertakings, but with the small ones. For these, as for the leaders of the industry, he has formed a very sincere and deep admiration. But he has realized the difficulties that some of the men in charge of the small undertakings are up against; and he has been struck with the devotion, the zeal, and the adaptability with which they meet their difficulties. He sees in the industry a new spirit of inquiry and of research, and a new feeling for efficiency and service, which, though not entirely due to the Gas Regulation Act, has been stimulated by it. In this connection, one of the problems the industry will, in his

opinion, have to face, is what should be done with the small and very small gas undertakings. How are we to combine with such undertakings technical efficiency and commercial success? It is a difficult question. Mr. Honey offers no solution. It is not a one-man job to do so. That it is a serious problem, and has become more so during and since the war, is well recognized; but there has been no real attempt to ascertain whether anything can be done to improve the position of such undertakings. Those who are chiefly concerned are those to whom the undertakings belong. But the gas industry is now looking after its affairs co-operatively, and it is to the general interests that the weak spots in the industry should be strengthened, if this is possible by investigation and advice.

The meeting last week shows how technically and commercially the industry is developing; and it has produced new matters for consideration. Year by year the Presidents of the Institution recognize the greater weight of responsibility that the position involves. Mr. Tagg has experienced this. To him his year of office has been a revelation, as it has been to his immediate predecessors, and will be to his successors. He has left the chair richly enhanced with the good feelings entertained for him in the industry. Mr. J. Ferguson Bell is now the President of the Institution. He enters office with the respect of all his professional brethren, and a high appreciation of his excellent work in the industry. His enthusiasm for its interests has always had existence; but it has grown. This year we predict it will be at high-water mark; and a year hence when he receives the newly-established and handsome Presidential Certificate, it will be handed to him with expressions of approval and unanimous endorsement of a year's work well performed, with results of considerable value to the industry. Mr. C. F. Botley becomes the Senior Vice-President, and Mr. John Wilkinson the Junior Vice-President. Their offices do not give them the prominence of that of the President. But they are on the high road to the chair; and in both of them the new President will find staunch supporters, as he will also in the trusty Hon. Secretary (Mr. W. E. Price) and the indefatigable Secretary (Mr. Walter T. Dunn).

The President's Examination of Current Position and Prospects.

CONSIDERATION of the address of the President leaves on the mind a feeling of great security for the industry; but at the same time one is very sensible of the fact that the security cannot be left to take care of itself. It must always be under the protection that comes from research and efforts to add to those things that are the essentials—economy, efficiency, and a broadening of the basis of business—to not only its continued existence but its reinforcement. The appreciation of this is seen on all hands, through the exertions the industry is making in investigating problems and to throw light on the paths which should be pursued, as well as by the provision of men well equipped mentally for the growth of responsibility which comes from the demands for, and the rendering of, greater service, in face of an intensified competition. Philosophically and with gratitude, we look on the progress that has been made. It is good. But when the fact is remembered that the British gas industry has a recorded statutory existence of some 112 years, and that it is only during the more recent ones that such large efficiencies and economies have been made in manufacture and application, one feels disposed profoundly to deplore the waste that is represented by the differences between past and present efficiencies. Slow progress, but still progress, was made at one time despite what we now know were uneconomical and inefficient conditions; and it has been the intelligence in the industry, the infusion of new blood into its technical and commercial work, and the incentive provided by competition, which have saved it, and made it more and more indispensable to the community. Upon those activities which have saved the industry and made it what it is to-day, there has to be development, and of an increasing order.

The President takes a period—the period of the union of the old Gas Institute and the Institution of Gas Engineers; and this year may be regarded as marking the "majority" of that union. Over that period he glances, and finds steady technical progress. When contrast is made from the point of view of efficiency between now and 1903, to our mind the cumulative effect of progress may be represented, not as "steady," but as remarkable. That progress would not have been possible either technically or commercially, and with such fulness, had it not been for the concomitant advances in the efficiency, and the production of a greater variety, of gas-consuming appliances, with an extended field of application. The President remarks upon the 3¾ million expansion in the twenty-one years of the number of users, who have been attracted by the facilities of cooking, room and space heating, water heating, and the innumerable industrial utilities of gas, which together have far more than compensated for the economies of the inverted incandescent burner compared with the consumption of the open-flame burner, which is receding more and more into the background of our recollections. But there are other points which may be emphasized. One is the greater service now rendered than formerly (owing to progress) to the consumers per unit of gas consumption, and a second is the increasing applications for service, both of which are important factors in the security of the interests of the industry. This is incidentally recognized by the President, when—referring to the average increase in the volume of gas sold (2·3 p.ct. per year) during the 21 years—he says it is evident the increased sales are due to new applications, as well as to additional users, as the relation of the maximum daily output to the annual output for thirty of the largest undertakings has improved from 1 : 203 to 1 : 251, or, in other words, the load factor has risen from 56 to 69 p.ct. This is a matter of gratification, though we cannot suggest that much importance should be attached to such figures in view of the development of room heating, which may altogether by long-day use in severe (particularly cold and foggy) weather cause the maximum day's output to take serious flights. Against this, the means for rapid production that are available enable us to look upon such flights, given the fuel supply, with perfect equanimity.

The President reviews the history of the electricity-supply industry, and points to the progress it has achieved, technically and commercially. That is a matter which must not be overlooked, any more than must be ignored the fact that during the last five years for which statistics are available, despite the increase in the use of electricity, the increase in the consumption of gas has exceeded that of any preceding quinquennial period. The information given by the President as to the doings of the Electricity Commissioners is interesting, but to it a proper significance must be attached. The main duty of the Commissioners was intended to be to centralize electricity generation. The records show that in this matter they have not so far been highly successful. They may have defined electricity-supply districts covering almost the whole of the country; but the Joint Authorities established are overwhelmed by the number of District Advisory Boards that have been instituted, and the powers of the former and of the latter are as wide asunder as the poles. The one embodiment is not the same as the other. But there is a further fact which emerges from the operations of the Commissioners in another direction, and which, one imagines, will have a large neutralizing effect upon the early realization of co-ordination and centralization of generation. The President points out that the Commissioners have sanctioned a gross addition of nearly 1¼ million KW. to the plant capacity of authorized undertakers, representing an increase of about 50 p.ct. of the plant capacity in 1920; and they have approved additional loans for local authority undertakings amounting to nearly 37 million pounds. Of course, the Commissioners were not created to starve existing undertakings; but the figures suggest to us—in view of the complaints of the manufacturers of electrical plant as to the sluggish nature of new business—that the existing authorized undertakings have manœuvred with excellent foresight to obtain sanctions which will help to defer the completion of the (to them) doubtful schemes of concentration. Then again, admitting that fuel consumption per unit generated has diminished through more efficient plant, and while not denying the accuracy of the Commissioners in stating that "such economies serve to emphasize the importance of the centralization of generation from the point of view of the conservation of fuel," it must be remembered that these economies have been effected under the existing generating *régime*, and not through any centralizing work that the Commissioners have accomplished. Moreover, while such economy tends to the conservation of fuel per unit generated, it should not be forgotten that fuel is not a large item in the total over-all costs, including capital and maintenance charges. Furthermore, the conservation of the

coal resources of the country would not be served by centralization of electricity generation if the electricity were to any considerable extent applied to heating purposes. And again, while generating concentration may serve to reduce the average fuel consumption per unit, and while the operations in the areas of electricity supply may improve the load factor, to all this there would be a set-off by increased costs for, and augmented losses in, transmission. This comment is not made with a view to suggesting that what the electricity industry is doing, apart from generation centralization, is of a character to be ignored. It is not. Meritorious progress is being made by it. Our business, however, is not only to keep an eye on that progress, but to work for the attainment of still greater advance for our own industry.

This progress is to be attained by making our own service still more attractive. The most important element in attractiveness is cost; and factors in cost are economy and efficiency. The President therefore discusses some of the principal items included in the charge for gas, commencing with the question of capital and depreciation, in which connection he raises some controversial points as to the latter, with which probably certain financial experts will disagree as applying to particular cases, but with which there will be agreement regarding the position generally. Naturally, through the sinking-fund repayments of local authority gas undertakings, and the large amount added to capital by gas companies through stock and share conversions and consolidations, the nominal capital of the latter is heavy in contrast with the former per million c.ft. sold. In 1883, 77 of the principal local authorities had £655 outstanding per million c.ft. sold, and in 1921 £268; while 128 companies in 1883 had a capital of £665 per million c.ft., and in 1921 £683, £207 of which latter is represented by stock and share conversions. This means that, had these conversions not taken place, the capital of the companies would have been in 1921 £476 per million, as compared with £268 for the local authorities. The £476 is wonderfully good, considering there are no sinking fund repayments, as in the case of the local authorities. There is no question that the President's examination of this matter has led him to the conclusion that the provision for depreciation has been on the part of gas companies totally inadequate, and more so now in view of the higher cost of plant required for replacements, which condition there is little prospect will be materially relieved for some time to come. That is the general deduction from the examination; but naturally the President does not attempt to define the form adequate depreciation should take, seeing that it must necessarily depend on local circumstances and existing statutory powers. Still there is no doubt that "some companies could with advantage make further provision out of revenue, unless they are working under a sliding-scale, and prefer to apply surplus profit to this end, instead of paying dividends in excess of the standard." In view of the meagreness of the standards in many cases, and the ideas of investors of capital as to the return they should have, there is little chance that the latter suggestion will be received with any conspicuous enthusiasm. However, the examination of capital expenditure and depreciation does not carry us far in effecting any immediate reduction of the cost of gas. We must assume that care is usually taken to get the best return in plant for the capital expended; but the provision of larger depreciation now, other than at the expense of the provider of capital, would not immediately affect the price of gas in the lower direction, though it might in the time to come. The immediate tendency would be rather to increase the price. Then the President does not hold out hope of any early reduction in the cost of coal, or of any substantial lowering of wages. And oil is an uncertainty.

Thus gas undertakings are left to hope for further reductions in the price of gas by operating for extended business, increasing the values of coke, and producing higher efficiencies and economies. Much is being done now in extending the gas business; but more activity is required by many individual gas undertakings. Coke has been taking an important part in effecting reductions of the price of gas. As the President points out, the coke position has been entirely altered from what it was before the war; and this has been brought about largely through the supply of gas of a lower calorific value per cubic foot than obtained pre-war, through changes in manufacturing system, and through the increase in the exports of coke—amounting last year to no less than 1,200,000 tons. Thus the quantity of coke available for home consumption was probably about 6 million tons, compared with 7·4 million tons in 1913. So that the surplus production which kept coke prices low before the war has disappeared; and the ratio of coke to coal prices has changed to the advantage alike of producers and consumers of the former. But as things are trending, the development of new markets for coke must not be neglected; and the President turns to the supply of a solid fuel for domestic purposes which will compete in price with coal, and prove as attractive in use. The President was admirably non-committal in this matter—simply referring to the low-temperature system, and the production of a suitable fuel by the arresting of the high-temperature carbonization of coal and coke briquettes at a stage at which about 5 p.ct. of volatile matter would be left in the coke. There are other suggestions; and in the end we are of the view that, all things considered, the production of a smokeless solid domestic fuel of a different order from the present gas coke will be from a high-temperature process. One of the possibilities is that this will follow the lines of the (as the President puts it) pre-treatment of the coal in order to effect quicker and more uniform heat transmission, increase the rate of carbonization, reduce the cost of manufacture, and produce a coke which will be freely and preferably used in substitution for coal.

The President is cautious. He makes no prediction or definite assertion regarding the future. He observes the trend of thought and investigation; he sees the possibilities; and there is a note of satisfaction, which is intensified by the energy with which research is being conducted in the industry. In this connection there is a suggestion, or—may it be termed?—a forecast. Any increase in the activities of the Institution in the matter of research, the President suggests, would involve the appointment of a technical officer, who should be a gas engineer of experience. We would suggest that such an officer should be not only a gas engineer, but one qualified also as a gas chemist. However, it is the President's view that, in any event, such an officer would be invaluable to the Institution in its capacity of technical adviser to the other organizations of the industry, and in the assistance he could render to the standing Technical Committees. There is also the development of co-operation for technical advancement between the users and manufacturers of gas plant and appliances. The worth of this has been tried, fully tested, and has been found to be invaluable. A further important contribution to the advancement is the technical education scheme.

Considering well all these matters, put with such conspicuous clarity by the President, we leave the address with a feeling that through it an excellent service has been rendered to the industry. There is in it a call to all engaged in gas supply—a call to them individually and collectively to recognize their responsibilities in these times, and to work for the reinforcing of the security which the industry possesses, but which will be lessened by neglect with others busy. The time was very opportune for this survey.

Reports and Papers.

THE literature generally of the gas industry has been considerably enriched by the research reports and papers contributed to the proceedings at this meeting. They all show the advances the industry is making, and the higher efficiency it is bringing into account. Viewing all that is being done and the ardent work in progress to achieve new gains, it would be impossible to place any definite limits to the industry's potentialities. The more one explores the work, the greater the reluctance to prophecy. Research, investigation, and practical improvements which come from experience are making their economic impression throughout the industry's operations. One cannot take a single feature of the technical part of last week's proceedings without receiving satisfaction on this point. In our "Review of the Proceedings" which follows almost immediately after this page, essay has been made to extract the salient points from the contributions. But this will not satisfy the technical student, or those in search of the fullest information on particular subjects. They will refer to the reports or papers to satisfy their requirements and to examine the details and the elucidating illustrations. There is no one contribution we would single out for special mention. They are all valuable. But we must express a word of acknowledgment of the careful and expanding work which is being done in the Coal Gas and Fuel Department of the Leeds University, under the supervision of Prof. Cobb, by his enthusiastic staff of research workers—to the great advan-

tage of the gas industry at large. So far as their reports are concerned, it will be found that, in addition to the summary in our "Review," after the reports themselves, each investigator supplies a *précis*, which we also publish.

Progress of Work under the Gas Regulation Act.

WHEN speaking at the President's luncheon on Tuesday last week, the Director of Gas Administration took the opportunity of referring to the progress that has been made with the issue of Orders under the Gas Regulation Act. The statement is not only interesting, but highly satisfactory, having in view the amount of work that has been involved. Powers have been given to something like 415 companies to work on the therm system, and to 134 local authorities—making altogether 549 undertakings. Of the remaining undertakings there are 65 companies who have not obtained powers to charge by the therm, and there are 167 local authorities. The 65 companies, however, only represent 3 p.ct. of the total amount of gas sold by companies—97 p.ct. of the gas supplied by companies being sold under the therm system. In the case of local authorities, something like 52 p.ct. is being sold under the system. Since the passing of the Act, 124 undertakings—92 of them being companies and 32 local authorities—have applied to the Board of Trade for Orders under section 10. Considering the expense, delay, and trouble that would have been involved had the industry been obliged to go to Parliament for those 673 Orders, it must be agreed that the operation of the Act has been a benefit to the industry. Another remark with which there will be agreement with Mr. Honey is that taking the long view—we have to take a long view in these matters—there has been no measure which could be so truly described as "the charter of the gas industry" as the Gas Regulation Act.

At the Exhibition.

As time passes, small changes and improvements are made in the Gas Exhibit which produce a still greater perfection, and add to the attractiveness. In all works of art or of utility, one can generally see where a little alteration would add to the effect or usefulness. The Gas Exhibit is a striking exemplification of the combination of art and utility. This is the verdict of men and women competent to judge; and when such a happy union can be made and the utility has a proved economy and efficiency, it cannot fail to appeal. The Exhibit is confessedly a revelation to many; and it is attracting a good share of attention. People are talking about it as much as, if not more than, of any individual exhibit in the Palaces of Industry and Engineering. The talk is inducing other people specially to visit it; and therefore the share of attention the gas industry is receiving at Wembley is good. The 5 million mark in attendance at the Exhibition was passed several days ago; and judging from visits paid last week, the numbers are swelling day by day. The popularity of the great display is decidedly in the ascendant. Another point to be noticed is that the electricians are not very confident of informing visitors that gas cooking dries up food and taints it. If they do, visitors who have enjoyed the dainty fare at the Lucullus Restaurant, or the more ordinary meals at the Regent, Stadium, or other restaurants or cafés at the Exhibition, and who know that the cooking is by the agency of gas, marvel as to the foolishness which denies the facts of the immediate and day-by-day evidence. But that such foolishness does exist in the electricity supply industry is testified to by their weekly prints and circulated literature. That by the way. Last week we saw that the hope was expressed by the Duke of Devonshire that the British Empire Exhibition would be able to meet its liabilities in full. Even if the Exhibition does not do so, he maintains that it is a success in every other way.

The Smithells Testimonial.

A reference to this matter by Prof. Cobb at the meeting of the Institution last week disclosed a gratifying position. After defraying the cost of painting a portrait of Prof. Smithells, by Mr. Fiddes Watt, R.A., there will remain upwards of £2000 for the endowment of a scholarship at the University of Leeds.

Sulphate Prices on the Nitrogen Basis.

The British Sulphate of Ammonia Federation have been addressing fertilizer manufacturers, agricultural merchants, and co-operative societies on the subject of the relative nitrogen values of sulphate of ammonia and nitrate of soda; and they have also taken the very proper step of removing the obscurity in this respect which has previously existed through sulphate prices being based on an ammonia basis, while the prices of most other forms of nitrogenous fertilizers are on a nitrogen basis. But that obscurity will no longer exist, as the Federation have abandoned the old basis. Henceforth, in order to facilitate comparison, the maximum prices quoted will be for 21·1 p.ct. nitrogen. To get an exact comparison of price with nitrate of soda, the price of sulphate of ammonia should be multiplied by 15·5, and divided by 21·1. The Federation are prepared to supply, for July and August delivery, sulphate of ammonia for home agricultural use at £14 per ton for neutral quality, on the basis of 21·1 p.ct. nitrogen. The unit value of nitrogen in this price for neutral quality is about 13s. 3d., whereas the unit value in the present price of nitrate of soda is about 16s. 8d. When the price of nitrate is £12 per ton at British ports, sulphate of ammonia is worth well over £17 per ton delivered. When sulphate costs £14 per ton, nitrate should not cost more than £10 5s. 8d. per ton. A rough comparison may be made by multiplying the price of nitrate by 7, and dividing by 5. Thus if consumers are asked to pay £13 per ton for nitrate, and they can get sulphate for £14, it can be seen at a glance that the price of nitrate is about £3 per ton too high.

Tankless Holders.

There was a model of a tankless gasholder on view in one of the rooms adjoining the lecture theatre of the Institution of Electrical Engineers in which our own Institution held their meeting last week. The model is described and illustrated in our Review of the Proceedings.

Coal Exports.

The exports of coal during May continued at a lower level than in 1923. The month saw a total shipment of coal of all sorts of 5,479,875 tons, compared with 7,684,405 tons in May, 1923, and 5,057,230 tons in May, 1922. The value for May this year was £6,678,328; for the same month of 1923, £10,588,417; and for that of 1922, £5,790,288. The gas coal exported in May was 769,291 tons, which compares with 903,876 tons in May, 1923, and 729,274 tons in May, 1922—the values being respectively £910,773, £1,168,485, and £816,885. The value per ton this year averages £1 3s. 8·1d. In the five months ended May, the total coal sent abroad was 26,248,766 tons; 1923, 33,220,230 tons; 1922, 22,390,312 tons. In these quantities, there were 3,442,586 tons of gas coal (1924), 3,923,019 tons (1923), and 3,185,595 tons (1922).

Gas Coke Shipments.

There has also so far this year been a shrinkage in the quantity of gas coke exported. In May the amount was 38,616 tons, as against 64,333 tons in the same month last year, and 23,742 tons in that of 1922. The values were respectively £69,203, £100,448, and £33,049. The average value per ton in May was £1 15s. 10d. The amount of gas coke exported in the five months was 408,092 tons, compared with 446,771 tons in 1923, and 293,350 tons in 1922.

Sulphate of Ammonia Exports.

The quantity of sulphate of ammonia shipped in May was 18,119 tons, compared with 21,476 tons in May, 1923. In the five months, 117,525 tons were sold abroad, which contrasts with 99 495 tons in the corresponding period of last year.

Lime for Thawing Ground.—For those engaging on winter street work where climatic conditions are severe, the "American Gas Journal" says the following "wrinkle" is well worth bearing in mind, should it be desired to draw the frost from frozen ground in order to get at a pipe beneath. At the spot where it is determined to dig, lay out the size of trench desired, and pick out the frozen surface to a depth of 8 or 10 in. In the hole so made, put in enough unslaked lime to make a good thick bed. Do all this in the evening, if possible, and, upon leaving, throw such a carefully judged quantity of water over the lime as will start it slaking and yet will keep it "working" for the longest time practicable during the night. Throw a lot of straw and a canvas over the whole, weighting it with stones and boards round the edge, to conserve the heat.

INSTITUTION OF GAS ENGINEERS.

ANNUAL GENERAL MEETING,

AT THE

INSTITUTION OF ELECTRICAL ENGINEERS, VICTORIA EMBANKMENT, LONDON,

JUNE 24, 25, and 26, 1924.

President: SAMUEL TAGG, Esq., M.Inst.C.E.

REVIEW OF THE PROCEEDINGS.

[For Full Report see p. 79.]

A SUCCESSFUL meeting—and too big a meaning cannot be attached to the adjective. It was, in fact, a success in every sense of the word. Everything combined to make it so. The weather was of a luxuriant order—a kind to which we have grown unaccustomed. Perhaps the contrast from what we had been experiencing was a little too great for comfort; but though it continued throughout the week, there was no grumbling over there being too much of a good thing. The fraternal spirit was everywhere; and the proceedings throughout the meeting were of such an attractive nature that no one complained of lethargy and excused it as being a concomitant of the heat.

Mr. SAMUEL TAGG, M.Inst.C.E.
President of the Institution of Gas Engineers.

Morning, mid-day, and afternoon, there were the customary scenes near the meeting place, in the vestibule, and the anterooms. In the lecture theatre prior to the appearance on Tuesday morning of the President, Mr. Samuel Tagg, M.Inst.C.E., and the Council, there was the usual hum of conversation, and hearty greetings on all sides. The theatre was well filled; and it was filled to the extent that even standing room was occupied during the delivery of the Presidential Address. Mr. Tagg has been a popular President—popular because of a transparent sincerity of purpose, and because he is sound to the core in whatever position he fills or in whatever advice he tenders; and withal he is courteous to all. It is part of an innate and not a cultivated disposition. So when the President came on Tuesday morning, he was enthusiastically greeted. With him was Mr. James Paterson who would have succeeded to the chair had not untoward events intervened. There was the President-designate, Mr. J. Ferguson Bell; and there were companions who had preceded in the chair—Mr. T. Hardie and Mr. J. D. Smith. From Wales there were members of the Council—Mr. H. D. Madden and Mr. Octavius Thomas. These were round the semi-circled table, with the faithful and ever-lively Hon. Secretary (Mr. W. E. Price), and the Secretary of unquenchable energy (Mr. Walter T. Dunn). His Worship the Mayor of Preston (Alderman F. W. F. Mathew) honoured the President and the Institution, and later on bore witness to the President being as good a citizen as he is Gas Engineer and Manager to his Company. The somewhat sombre appearance of the theatre was relieved by two bouquets of roses—the red rose of Lancashire.

There was a little preliminary business, including the reading of greetings from the Société Technique du Gaz and the American Gas Association. A suitable reply was at once dispatched to France, and in due course one will be sent to America.

The Institution Gold Medal.

There was a paper at the Belfast meeting which was selected as having great distinction in regard to technical merit. It was on "The Flow of Gas in Pipes," and was by Mr. Stephen Lacey, B.Sc. On the recommendation of the Council, it was decided to present to him the Institution Gold Medal. This it was the pleasurable duty of the President now to do. As it was handed to Mr. Lacey, accompanied by choice and justified remarks by the President, there was loud applause, which was a sufficient endorsement of the Council's wisdom in the matter. Very sincere appreciation of the honour was expressed by Mr. Lacey.

First Recipients of Diplomas.

Then there was further pleasure for the President; and it was to hand diplomas to those who have had the honour of securing the highest distinction obtainable under the Education Scheme. The recipients were Mr. P. C. Gardiner, of Tottenham, and Mr. J. Hood, of Shrewsbury. There were hearty congratulations upon their success.

President's Address.

Without delay the President commenced his address; and it was quickly realized that into it he had put his heart and soul. There was no attempt at eloquence. It was a studious composition; the work of a thinker—one who contemplates those things that are existent, and that are likely to be; the work of one who considers whether the best is being done in the current circumstances, and as to what (if anything) would be better. He looks upon the progress of the industry as excellent. He considers the history and advance of the sister industry; and he examines some of those things that are being done with the view of accentuating the pace of the progress of the latter. In the struggle for commercial supremacy, it will be a case of the fittest for each particular purpose; and there is a large confidence on the part of the President as to which is the better for objects which are of universal importance. In the finance of the company section of the industry, the President appears to detect a weakness in the insufficiency of the allowance for depreciation, which, we fancy, he fears will, if not rectified, have a prejudicial effect upon company undertakings in the future. But in all other respects—particularly in the education of men in an appropriate manner for the work of the industry—he finds that things are shaping well, except that he can hold out no promise, or very little, that the prices of materials and of other requirements of gas undertakings will make any substantial recession. He looks to economy and efficiency, and to the production of a quality of coke which will command good prices for domestic purposes, helping to forward prosperity. His comments on the question of coke are well worthy serious consideration. The whole address is based on the contemplation of the present, with the view of guiding us in our advance into the future. Comment and review of the address is made in our editorial columns; and therefore this brief reference will here suffice. As the last words of the address fell from the lips of the President, the applause was great and continued.

Cheers greeted Mr. James Paterson as he rose to move a vote of thanks to the President. From his novitiate days, he has had Mr. Tagg as a friend; and therefore he can speak of personal qualities from long acquaintance and enjoyment of them. Mr. Paterson spoke in congratulatory terms of the address, and that in no polite formal manner, but with an obviously pure sincerity. The same applies to the remarks of the seconder, Mr. H. D. Madden. The testimony from Preston, as voiced by the Mayor, made the bronzed face of the President take a somewhat deeper hue. The remarks of His Worship must be read in our general report to get their full import and flavour. *Multum in parvo* characterized the President's reply.

Annual Report and Accounts.

These were next submitted. On this occasion there was no comment; and the Council were not from any quarter accused of having done those things which they ought not to have done, and of having left undone those things which they ought to have done. Therefore the statements of the year's proceedings and of finance were unanimously adopted.

The Education Scheme.

A new feature, and a welcome one! Mr. F. W. Goodenough, the Chairman of the Advisory Committee on the Education Scheme, submitted the Report of the Advisory Committee, which first informed us as to who are the members of the Committee, the Board of Examiners, and the Consultative Committee. It appears that much of the work in the past year has been in the nature of foundation laying; and all will ally themselves with the hope of the Committee that the foundations have been laid broadly and deeply, and have been such as will worthily bear the edifice which the passing years will see raised thereon. There have been difficulties with technical institutes, and in getting in some areas a sufficient number of students to justify the formation of the necessary classes. But it is hoped to overcome this by making particular towns centres for undertakings within a radius (say) of 20 miles; and, in this connection, suggestions are made as to how gas undertakings can render to students financial aid and other facilities. Nothing has been left undone which could be done in interesting the junior members of the staffs of gas undertakings in the scheme, as we well know; and in this work Mr. Walter Hole, the Organizing Secretary, has taken a very active part. Students should remember the value that the certificates of the Institution will be to them in the future when they are candidates for appointments. The report gives a list of technical schools where the scheme has been introduced. The total number of candidates examined in May last was 60, of whom 36 were in Section I. and 24 in Section II. It is hoped and expected that the scheme will be in operation in Scotland next session. Another point made is that experience of the scheme in operation suggests that an extension of its scope is needed in a downward direction; and minor group courses of a suitable character are now receiving earnest consideration.

Mr. Goodenough was proud and honoured that the task of presenting the report fell to his lot, though, as he expressed it, the size of the report is altogether in inverse proportion to the importance of the subject. There was gratification on the part of the members as he mentioned the names of those who have put in hard work, or have assisted by sound advice and co-operation, in getting the scheme established. There was applause for them all, and especially for the extraordinarily energetic Organizing Secretary, Mr. Walter Hole. There is no pretence that the scheme has reached the acme of perfection. Experience will bring that about; but, as it progresses, there will also inevitably be a raising of the standard of qualification of those who obtain certificates and diplomas—to the advantage of themselves and of the gas industry. There was an appeal to all who have the power to make the scheme an increasing success. Many good things were said respecting the scheme and its importance by Mr. James Paterson, M.A., who seconded the adoption of the report, which was carried.

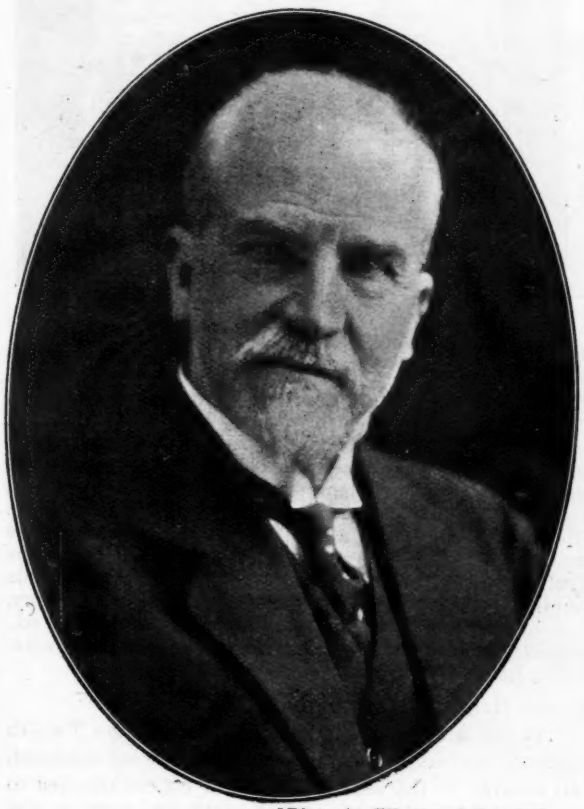
Some Revising Points.

There had been circulated among the members two or three drafting amendments in the scheme for the education and certification of those engaged in the technical work of the industry; as well as certain revisions of the Articles of Association, bearing upon the subject of admission to the membership classes of the Institution. In part, these also had reference to the education scheme. The nature of the amendments will be found in our general report. They were carried unanimously.

Work of the Investigation Committee.

As in the character of their work, there is a thoroughness in the manner in which the Gas Investigation Committee of the Institution and the Leeds University submit their reports. This thoroughness finds expression in volume and detail. In the Eleventh Report, we have presented for consideration 35 printed pages with plates containing a number of diagrams. In the Twelfth Report on Waste-Heat Boilers, there are 41 pages of matter and several plates. Some of this may not appeal to the purely practical man, but not a line is excess so far as the student of these matters is concerned. The two reports mentioned start with a general introduction and a number of personal references. There is gratification that Prof. Arthur Smithells, who has completed his term of distinguished

service at the University of Leeds, has retained his Chairmanship of the Committee. On the Committee, Mr. H. Pooley, of Leicester, has taken the place of Mr. H. E. Bloor, whose other pressing duties compelled his resignation. The work which Prof. John W. Cobb has been supervising during the year has not been so much in new subjects as on logical developments of investigations already in hand and partially completed. Mr. James W. Wood has been further engaged on the work of aeration in atmospheric burners and air injection; but he has had to work largely single handed, owing to the necessity of transferring his assistant, Mr. G. B. Howarth, to Dr. Parker. However, Mr. Wood's work during the year has been to make a careful examination of the aeration accompanying the use of gas in several typical burners—ring burners, and those of the gas-fire. The influence on aeration of varying the gas pressure and of altering the specific gravity was investigated, and the difference brought about by the burner case warming up in use. Some working rules have been deduced, which, it is hoped, will prove of service in practice, apart from their scientific interest. Dr. A. Parker and his assistants—Mr. H. Kerr and Dr. A. C. Monkhouse, have been occupied in investigating the performance of



[*Photo. by Elliott and Fry, Ltd.*

Mr. J. FERGUSON BELL, M.Inst.C.E.

The New President.

waste-heat boilers attached to continuous vertical retort settings at Birmingham. The Gas Research Sub-Committee were offered during the year, with the permission of Dr. Carpenter, a report from the laboratories of the South Metropolitan Gas Company on the subject of the practicability of replacing by methane some of the carbon monoxide of water gas and coal gas. The communication is interesting and valuable. Thanks are tendered to the Birmingham Corporation and the Leeds Corporation Gas Departments and to their chief officers for the facilities they have allowed the Committee for their investigations. Reference is also made to the completion of the experimental gas plant erected by Mr. Henry Woodall, with the co-operation of some friends, as a memorial to his father, Sir Corbet Woodall. It is hoped, and the hope has a big justification, that the plant will prove of great service to the industry.

Aeration in Atmospheric Burners.

This work is a continuation of that described in the Ninth Report; and there has now been a detailed study of aeration conditions in typical ring burners and in a gas-fire. Taking the former first, two typical drilled ring burners of different patterns were used. It should be explained that throughout the tests, they were worked at various gas rates and pressures with the same "fixed" nipple and without any alteration or adjustment of the air-inlets. Gases of specific gravities 0·4, 0·5, and 0·6 were used, pressures up to 3 in. water gauge, and gas rates up to 25 c.ft. per hour. Another series of tests was made with gas of specific gravity 1·0. With regard to the application of the results, it is clear that it would be unwise to generalize as to quantitative relationships among the various conditions involved, from data obtained with only two burners. On the other hand, it is believed that the burners were representative of one large class of domestic appliances, and were used under typical working conditions. It is highly probable therefore that the data indicate at least approximately the order of the changes in aeration which may be expected with such appliances in practice, and may be to that extent a useful guide.

For gas of any one quality, the air-gas ratio increased very rapidly with pressure at low figures; but the further increase in aeration at gas pressures above 1 in. water gauge was relatively small, being less than 10 p.ct. in all tests, and with the shorter of the two burners less than 5 p.ct. Both at equal gas rates and at equal gas pressures, the air-gas ratio always increased when the specific gravity of the injecting gas was increased. For gases of different specific gravities, the air-gas ratio was, however, definitely not simply proportional to the specific gravity of the gas, whether comparisons were made on the basis of equal pressures or equal gas rates. If comparisons were made at equal gas pressures (for either burner), the rate of air injection in c.ft. per hour was approximately the same for all the gases tested—*i.e.*, independent of specific gravity. Since at equal pressures the gas rate was approximately inversely proportional to the square root of the specific gravity, this means that at constant pressure the air-gas ratio was nearly proportional to the square root of the specific gravity of the gas. If attention is confined to the specific gravity range 0·4-0·6, the above relationship can be simplified thus: The percentage change in air-gas ratio is one-half the percentage change in specific gravity for equal jet pressures—*e.g.*, for an increase of 10 p.ct. in sp. gr. (say) from 0·48 to 0·53, the air-gas ratio would increase by 5 p.ct, or from (say) 3·00 to 3·15. Owing to the fact that the change in air-gas ratio was small over the working pressure-range of the burners (say, 0·5-3·0 in. water gauge), the relation given also applies for these two burners to comparisons made at equal gas rates.

The influence on aeration of lighting the burners and allowing them to become hot in use was then separately examined. In the case of ring burners working under ordinary conditions of use, the mere act of lighting the burner produced no measurable effect upon the degree of aeration. When the burners had been in operation sufficiently long to become hot, there was a reduction in air-gas ratio as compared with the cold burner working with the same gas quality, rate and pressure, which differed from the type of burner used. For the short shank burner, the reduction in air-gas ratio was about 10 p.ct. For the long shank burner, the reduction in air-gas ratio was about 15 p.ct. From special consideration of experiments made with the gas-fire when hot and when cold, and from general consideration of the factors involved, it would appear that the conclusions arrived at with regard to the change in aeration with specific gravity and gas pressure for cold unlighted burners, might be applied with some confidence to the same burners when in their normal working state.

The aeration curves for a typical 14-in. gas-fire were determined, and showed similar characteristics to those of the gas-rings, except that beyond 1 to 1½ in. water gauge, there was a slight reduction in air-gas ratio as the pressure was increased; the gas-fire being tested with the gas unlighted. These characteristics were retained when the fire was lighted, but the air-gas ratio fell by about 10 p.ct. at all gas rates and pressures, within the range examined. This reduction was smaller than was anticipated from the tests with the gas-rings; and it is probable that the chimney pull produced by lighting the gas in some measure compensated for the reduction which might be expected to result from heating up the burner body. The report is an extensive one, and will well repay study.

Introductory Statements.

The report was introduced by Prof. Cobb. Illustrating the nature of the results, he stated that it was found that with a gas of specific gravity lying anywhere between 0·4 and 0·6, the percentage change in the air-gas ratio is half the percentage change in the specific gravity for equal jet pressure, so that for an increase of 10 p.ct. in specific gravity, the air-gas ratio would increase 5 p.ct. Another point is that when a gas-jet is turned on, it injects a certain amount of air. This was determined. Then the burner was lighted, and the condition as to aeration was again ascertained. It was found that, with ring burners, the mere act of lighting produces no measurable effect upon the degree of aeration; but when the burner has been lit for some time, and its casing warms up, the temperature conditions are altered, the resistance to the passage of the gas-air mixture is increased, and the aeration suffers to some extent. The falling-off is of the order of 10 p.ct. in the burners examined. There is no doubt that the results so far obtained go some way towards placing our knowledge of this all-important subject on a firmer basis. It is proposed to extend the investigation to other types of burners, such as lighting burners, both low and high pressure.

Different Qualities of Gas and Aeration.

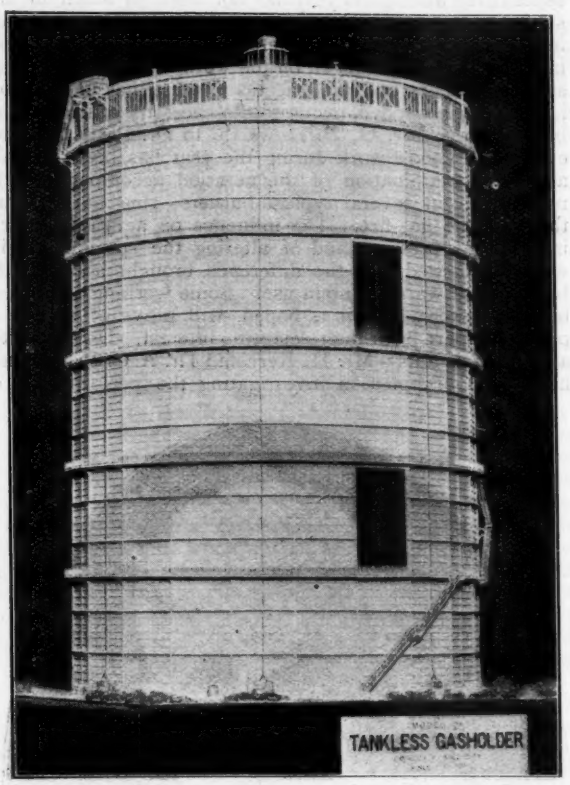
Mr. Wood emphasized the chief lines of the experiments and the objects in view, as well as the results, as more briefly indicated by Prof. Cobb. In the discussion, there was no serious criticism of the report. Suggestions were made (as the full account shows)—especially by Mr. W. Newton Booth and Dr. E. W. Smith—as to lines of further work which would be useful. However, the fact that Mr. J. Ferguson Bell regarded as important the finding that specific gravities ranging from 0·4 to 0·6, so far as ordinary pressures are concerned, cause little alteration of the flame, induced Mr. Leather to suggest that it must be remembered that different qualities of gas require different amounts of air, so that the assertion that specific gravity does not alter very much the amount of air needed does not altogether meet the whole question of how much air a gas will want. There was agreement with this on the part of Mr. Newton Booth—in fact, he said that alterations in the air requirements of the gas have a very much greater effect on burner performance than an alteration in the actual amount of air injected by the burner. Variation in the specific gravity and in pressure of the gas have much less effect on the actual burner results than alterations on the air-consuming properties of the gas. It appears from what Mr. Wood said in replying to the discussion that it is fully appreciated that different kinds of gas require different amounts of air for complete combustion, but the point which is not agreed upon is whether it is ever necessary or advisable to supply the whole of the air to the burner as primary air.

The Smithells Testimonial.

In his introductory remarks in introducing the Eleventh Report of the Committee, Prof. Cobb mentioned the gratifying fact that, though Prof. Smithells is no longer Professor of Chemistry at the Leeds University, he is continuing to act as Chairman of the Committee. On the part of the members of the Institution, there was gratification over the announcement. There was also reference to the excellent support the gas industry has given, and is giving, to the steps that have been taken to signalize, by a testimonial, the services of Prof. Smithells in so many causes; among them several of large concern to the industry itself. After defraying the cost of the painting of a portrait of our friend by Mr. Fiddes Watt, R.A., there will remain upwards of £2000 for the endowment of a scholarship at the University of Leeds.

A Model Tankless Holder.

In one of the anterooms there was on view a model of a tankless gasholder; and it was the object of much interest during the intervals between the sittings. We had a photograph taken of it; and here present it to our readers. It was a scale model, showing a tankless holder of 4¼ million c.ft. capacity, 165 ft. diameter by 250 ft. high. A large number of holders of this type have been erected in France, Holland, and Germany—amounting in the aggregate to over forty. It is learned that this system of holder construction has recently been introduced into the United States; and a contract has already been entered into for a holder of 1 million c.ft. capacity for Michigan City. It is pointed out that apart from the economy in



THE MODEL OF A TANKLESS GASHOLDER.

construction and foundations, especially in the larger types, many collateral advantages are claimed, since there is no tank and its water content, no cups and grips, dispensing with all anxiety of wear and tear at wind and water level. The gas is expelled by a disc which can be made to give any required pressure, constant throughout. It may be mentioned that the sole rights for the manufacture in this country are vested in the Tankless Gasholder Company, Ltd., under the control of Messrs. C. & W. Walker, Ltd., Samuel Cutler & Sons, Ltd., and Ashmore, Benson, Pease, & Co., Ltd.

Waste-Heat Boilers—Preliminary Work.

At the afternoon sitting the same day, the Twelfth Report of the Gas Investigation Committee was considered. This referred to the use of waste-heat boilers attached to continuous vertical retorts, which work has been in the hands of Dr. Parker as Research Chemist, with Mr. Kerr and Dr. Monkhouse as assistants. It may be well to preface the year's work by stating that the inquiry into the thermal and chemical efficiencies of methods of manufacture of different grades of gas was commenced by an investigation of the process of steaming the charges in the retorts of the continuous vertical installation at the works of the Bothwell and Uddingston Gas Company. The results of the Uddingston tests (which appear in the Fourth Report) proved that, with proper control of the conditions, considerable advantages are to be gained by moderate steaming. The thermal efficiency of gas production rose from 54·4 p.ct. without steam to a maximum of 62·1 p.ct. with steam. It was afterwards calculated (*vide* Sixth Report) that if the steam required for the retorts could have been raised in waste-heat boilers, the efficiency of 62·1 p.ct. would have been increased by approximately 6 p.ct. to 68·5 p.ct. The next step in the investigation was carried out at the Adderley Street Works of the Birmingham Gas Department, with the object of determining the efficiency of production of blue water gas as ordinarily practised in a plant without waste-heat boiler. It was found that, taking into account the steam required for the generator and turbo blower, the efficiency of gas production averaged 46 p.ct.; and it was

calculated that, if the steam required had been raised by means of a waste-heat boiler, the efficiency of 46 p.ct. would have been increased to 56 p.ct. This conclusion was supported by the results in the Seventh Report, which describes an investigation of the manufacture of carburetted water gas in a Humphreys and Glasgow plant with attached waste-heat boilers. The amount of water evaporated in the waste-heat boilers was sufficient to supply the steam required for the generators, turbo-blower, and auxiliary plant, under the conditions of the tests.

It was pointed out in the Sixth Report that an alternative method of diminishing the loss of heat due to the potential heat of the blast gases in the manufacture of blue water gas might be to reduce the amount of carbon monoxide carried away by the stack, by changes in the method of operation of the plant, in so far as such changes could be made without prejudice to the efficient production of water gas during the run periods. This problem was investigated at the Adderley Street Works; and the results obtained were described in the Tenth Report. After a number of preliminary trials, several complete tests were carried out under different conditions. In one of the tests, the loss of heat due to the potential heat of the blow gas was reduced to 11·5 p.ct. of the total heat supplied as against 20 p.ct. in the Sixth Report tests. The reduction of 8·5 p.ct. in the loss from this source, however, was achieved at considerable expense in other directions. It was finally concluded that the manufacture of blue water gas by the intermittent process can be carried out more efficiently and with a greater output of gas per day when the ratio of carbon dioxide to carbon monoxide in the blow gas is about 0·9 than when this ratio is greater than unity—in other words, the amount of carbon monoxide in the blow gas should be rather more than the amount of carbon dioxide. From calculations of the heat available for use in a waste-heat boiler, it was also concluded that, even with the installation of a waste-heat boiler, the intermittent process would be more efficient under such conditions that the blow gas contained rather more carbon monoxide than carbon dioxide. It was then decided that an investigation should be made of the heat recoverable in a waste-heat boiler attached to an installation of continuous vertical retorts. This has been done at the Windsor Street Works.

Waste-Heat Utilization from Continuous Verticals.

The coal carbonizing installation at the Windsor Street Works consists of six separate ranges (designated A, B, C, D, E, and F) of Woodall-Duckham continuous vertical retorts. Attached to each range is a Babcock and Wilcox water-tube waste-heat boiler, through which the waste gas is passed before entering the chimney. The retorts of range D, which had been in operation for a period of five years without resetting, were not in the best condition. The waste-heat boiler, however, appeared to be in good working order; and various considerations led to the selection of Range D for the first part of the investigation.

Heat equations were constructed for the purpose of ascertaining the volumes of waste gases passed through the boiler per hour. From these volumes and the known composition of the gases, the equivalent weights of carbon were then determined. Figures given in the report show that the volumes of gas passed through the boiler per hour more than correspond with the weights of carbon gasified in the producers. A method involving the construction of carbon, water, and heat equations was also devised for the purpose of ascertaining the approximate amounts of the various leakages which must have taken place. From these equations it was found that approximately one-third of the difference in carbon weights in Test 1 and two-thirds of the difference in a second test were due to leakages of waste gas past the by-pass dampers and back again into the boiler. The remaining weights of carbon therefore represent the excess of leakages of coal gas, &c., from within the retorts over any leakages of waste gas which may have occurred through the retort walls in the opposite direction. The equations also proved that in addition to leakage of air into the waste gas-flues, water had entered an underground flue.

A further test was carried out on Range E, the retorts of which had been reset early in 1923, and in which the waste gas-flues are all situated above ground level. The weight of carbon gasified in the producers in this third test was 2520 lbs. per hour, compared with 2810 lbs. in the gas passed through the boiler as deduced from a heat equation. It would appear that the 290 lbs. carbon difference is to be accounted for mainly by leakages past the by-pass dampers.

TOWARDS THE CLOSE OF A MORNING SITTING.—SCENE OUTSIDE THE INSTITUTION OF ELECTRICAL ENGINEERS.

The principal results obtained during the three tests are given in a table in the report. The amounts of water evaporated in the boilers during the three tests were equivalent to evaporations from and at 100° C. of 39·4, 42·5, and 53·4 lbs. per 100 lbs. of coal (dry basis) carbonized, or 2·97, 2·85 and 3·41 lbs. per lb. of coke (dry basis) supplied to the producers. The net thermal efficiencies (*a*) represent the amounts of heat utilized in raising the net weights of steam available (due allowances being made for the power required for the fan motors and the boiler feed-pump) as percentages of the heat contents of the gases at the inlets to the boilers. The efficiency during Tests 1 and 2 was 37·4 p.ct. The efficiency of 44·7 p.ct. in the third test was undoubtedly due mainly to the higher average temperature at which the gases entered the boiler. The net efficiencies given (*b*) for Range D represent the same amounts of heat expressed as percentages of the heat values of the gases in the vertical down flue.

Expressed as percentages of the heat values of the fuel supplied to the producers, the net quantities of heat recovered were 20·7 p.ct., 20 p.ct., and 24·2 p.ct. respectively in the three tests. In the absence of waste-heat boilers, it would have been necessary to raise the same amounts of steam in boilers fired with solid fuel. On the basis of an efficiency of 70 p.ct., the solid fuel boilers would have consumed 8·6 tons of coke per day in Test 1, 8 tons in Test 2, and 12·1 tons in Test 3; the qualities of the coke being the same as those actually supplied to the producers. These weights therefore represent the amounts of fuel saved per day by the waste-heat boilers, quite apart from a reduction in labour charges. It has been calculated that the amounts of heat recovered in the waste-heat boilers in this investigation would bring up the efficiencies of gas production in normal working with continuous vertical retorts by about 6 p.ct.—*e.g.*, from 60 p.ct. to 66 p.ct.

Comments on the Report.

The discussion was an interesting one. Many points were made by Mr. J. S. Thorman, of the Gas Light and Coke Company, who was the first speaker. He thought that the temperature of the waste gases—308°, 324°, and 265° C. in the three tests—could with advantage have been reduced. If, for example, a temperature of 220° C. had been attained, instead of an evaporation of 3½ lbs. of steam per lb. of fuel gasified in the producers, 4 lbs. of steam would have resulted. It was mentioned in the report that the chimney shaft was doing 50 p.ct. of the work of dealing with the waste gases, the other 50 p.ct. being done by the fan. Was it worth while to deliver the gases back into the chimney shaft; and could not they be employed for some ancillary purpose—such, for instance, as heating water? He strongly favoured the adoption of fire-tube boilers in preference to the water-tube type, for the former could be cleaned while working, and the labour costs were by no means heavy. A factor of great importance in the maintenance of efficiency was the purity of the water; and in this respect, Birmingham was happy in having a supply of only 5° of hardness. At Stratford the hardness figure was reduced to zero by a Permutit softener; and after seven months' continuous working of the fire-tube boilers there, without cleaning, the tubes were as good as new, and the falling-off in efficiency was only 6 p.ct. Speaking of the recovery of waste heat generally, he emphasized the fact that there were equal opportunities for the application of waste-heat boilers to horizontal settings as there were to their use with verticals and water-gas plant. Often he had heard it stated that, with a combustion-chamber temperature of 1300° C., the temperature of the waste gases was 400° C. Theoretically, this was impossible, even with the most efficient form of recuperation, when the relative volumes of waste gases and secondary air were taken into consideration. Strictly speaking, the outlet temperature could not be reduced below 700° C. unless dilution occurred. Every horizontal setting was capable of producing 4 lbs. of steam per pound of fuel gasified in the producer, or 1200 lbs. of steam per ton of coal carbonized. The amount of steam required on a gas-works was about 720 lbs. per ton of coal carbonized; and if sulphate of ammonia was manufactured, this figure was raised to 850 lbs. Thus there was really no need for a solid-fuel fired boiler.

The fact that the heat wasted in the production of gas could provide more than all the steam required for its manufacture was also stressed by Mr. Leather. Some interesting remarks of a practical nature were forthcoming from Mr. Pearson, of Birmingham, who discussed the relative merits of water-tube and fire-tube boilers. Though the latter, he said, were more efficient *per se*, the former gave less trouble in practical working, especially where the water was of a hard character. The installation at the Windsor Street Works was more than capable of furnishing sufficient steam for the verticals. The estimation of heat leakage from settings was of great importance, and investigation on these lines, to afford information as to the economic limit of preventing carbon losses, would be greatly appreciated. Mr. T. Hardie criticized the method of arriving at the figure for the efficiency of the combined process of gas production and utilization of waste heat by combining the figures for gas production obtained at Uddingston and given in the Fourth Report of the Committee with those for the waste-heat boiler determined at Birmingham. Dr. Parker, replying to the discussion, submitted that the recuperation of further heat from the waste gases by passing them, on their exit from the waste-heat boiler, through an economizer, was not a straightforward problem, but one which bristled with difficulties. More power would be needed to drive the fan; and this would have to be set against any gain in the process. Also, condensation of steam would result in a liquid containing sulphur dioxide in solution, which would naturally cause corrosion. As to how far it was possible to prevent heat losses from settings—as a suggestion, by brick-lined metal flues—depends on the economics of the question.

Removal of CO from Town Gas.

The thanks of the industry are due to Dr. Carpenter and the South Metropolitan Gas Company for an account of researches, in the laboratories of the latter, into the question of the removal, by the agency of catalysts, of carbon monoxide from water gas and straight coal gas. Although the investigation has not yielded a process which could be carried out without adding to the cost of gas per therm, the record of the work done is valuable, in that it will save other experimenters traversing the same path, and simply realizing like results. The technical staff of the Company sought to devise, if possible, a cheap and efficient process to attain the end. That they have failed does not detract from the credit due to them for having made the attempt. It is generally agreed that the removal of carbon monoxide can be best achieved by making use of the fact that, in the presence of suitable catalysts, this gas reacts with hydrogen and steam. The reactions may be applied to the conversion of water gas to a methane rich gas, and to the replacement of carbon monoxide in ordinary straight coal gas by hydrogen or methane, or both.

In connection with the conversion of a water gas to methane rich gas, the communication reviews the work of Sabatier and subsequent investigators. But there were difficulties, and no one has established a process on an economical basis. The work carried out in the South Metropolitan Company's laboratories was with a view to increase the velocity of the reaction by means of a more active catalyst. The reaction is effected at a temperature of 285°-290° C., with a mixture of H_2 and CO in the ratio of 5 : 1 parts by volume. It was found that the rate of reaction could be considerably increased by the use of an activated catalyst; the optimum results being obtained with a nickel thoria catalyst. By the use of this activated catalyst, the reaction for the synthesis of methane may be increased seventeenfold. In the synthesis of methane from water gas, a technical process is outlined; but, owing to the necessity for removing sulphur compounds, and for adjusting the proportion of carbon monoxide and hydrogen from the hydrogenation reaction, the process would be too costly to be applied to the gas industry. The matter is discussed in the communication; and an approximate estimate of the cost of production of synthetic gas is made. In short, excluding the cost of the hydrogenation process, the estimated net cost of production of synthetic gas, free from carbon monoxide, and of a calorific value of 690 B.Th.U., is 10·9d. per therm, which shows that the production of a CO free synthetic gas from water gas is economically out of the question, unless some less expensive method can be found.

While the problem of the replacement of carbon monoxide in ordinary straight coal gas appears to be a simpler one than that of the production of CO free gas from water gas, since the hydrogen and carbon monoxide are present in this case in suitable proportions for hydrogenation to

methane, unfortunately the sulphur impurities must first be eliminated. The communication shows that to effect the complete conversion of the carbon monoxide by steam would not be economical owing to the large volume of steam required, and resort must be had finally to hydrogenation. It is also shown that the process for the removal of sulphur compounds and partial conversion of the carbon monoxide into carbon dioxide and hydrogen is complicated by the presence of unsaturated compounds in the gas. These compounds are fairly easily decomposed at the high temperature of the reaction with the production of carbon dioxide. There is no desire to lose valuable unsaturated hydrocarbons, and in town gas there is no use for carbon dioxide. In addition, a further heat loss is incurred owing to the exothermicity of the reaction. The total loss resulting from these three factors would cause a considerable increase in the cost per therm of gas produced.

The Sulphur Difficulty in CO Elimination.

The communication was introduced by Prof. Cobb, who emphasized its importance and general interest to the industry, and expressed his own personal appreciation of its value. Then Mr. Evans, in his customary brilliant style, gave an abstract of the work. The chief stumbling-block in the conversion process, he said, was that minute traces of sulphur immediately poisoned the catalyst, rendering it inactive—even such a small amount as one part in a million being sufficient to disturb the reaction. For completely eliminating sulphur compounds, a successful system had been brought out by the Badische Anilin und Soda Fabrik, but the trouble in connection with this was not theoretical, but a matter of hard cash. Financial considerations constituted the real difficulty of any practical application of the process as a whole; and the advantages gained were by no means commensurate with the cost. In this respect, then, the communication is of a negative order. But this fact does not detract from its worth or interest; and it may at some future date prove to be an important link in the chain leading to ultimate success.

The communication reminds us of the third William Young Memorial Lecture which was delivered by Dr. R. Lessing in 1914 before the North British Gas Managers' Association. In that lecture, Dr. Lessing dealt with catalysis in the gas industry. Dealing with the water-gas process, he referred to a very promising application of catalysis being in the direction of transforming a mixture of hydrogen and carbon monoxide into methane.

Testing Gas-Cookers.

The next matter for consideration was the special report of a Sub-Committee appointed by the Gas Investigation Committee to consider a standard method of testing gas-cookers, which is an acknowledged desideratum. The Chairman of the Sub-Committee is Mr. A. E. Broadberry. The Committee itself is a representative one, and consisted of gas engineers and technical representatives of manufacturing firms. The Sub-Committee appointed a small Committee to carry out the work, consisting of Mr. A. E. Broadberry, Mr. J. G. Clark, Dr. H. Hartley, and Mr. Arthur Forshaw (Convener and Secretary). An interim report was presented some months ago; and now this is the final one.

To carry out tests on cooker-ovens, the following information should be ascertained: (1) The normal maximum consumption; (2) the factor of safety; (3) the temperature-maintenance consumption; (4) the suitability for cooking. None of these tests can be omitted. This applies particularly to that for ascertaining the suitability for cooking, since, as is mentioned elsewhere, an oven may satisfactorily pass the first three which are physical tests, and yet fail to give good cooking results. After a definition or explanatory note of each of these, a description of the form of test recommended by the Sub-Committee is given. Following the tests is an Appendix containing details of apparatus required, test-room conditions, procedure, illustration of results obtained, and other useful information. We cannot enter into the mass of detail in the review. The full report (which shows the thorough character of the Committee's work) on later pages must be consulted.

It may, however, be briefly explained here that by normal maximum consumption is meant that maximum consumption which may be required for the initial stages of cooking operations. Experience has shown that this consumption is not higher than such as will heat the oven up from cold to 400° Fahr. in x minutes. x will vary according to whether the oven is "packed" or "unpacked." In a packed oven x = twelve minutes; in an unpacked oven, ten minutes. The heating-up test for determining the normal maximum consumption is described.

As to the factor of safety under conditions of use, as the result of variations in pressure and density of the gas supplied the oven may be called upon to consume more gas than the normal maximum consumption; and while the oven cock allows of control, it is necessary to ensure that the appliance shall be safe without the necessity of such external control. The Sub-Committee feel that if an oven can consume safely such an excess of gas over the normal as will result from a pressure increase of two-and-a-half times the minimum district pressure (at which the normal maximum consumption is ascertained), the appliance will be satisfactory. For this a smothering test is suggested.

As to the temperature maintenance test, if the oven satisfactorily passes the two previous tests, its comparative value as an apparatus for arresting the heat of combustion of the gas, and maintaining a cooking temperature, is to be assessed. For this purpose tests at two temperatures are necessary; and the modes of procedure are explained in detail.

Concerning the tests for suitability for cooking, it is mentioned that as soon as solid shelves or food, or both, are introduced into an oven, the distribution of temperature as shown by a thermometer is altered. An oven which may give excellent results in the temperature maintenance test may suffer from some disability when actual cooking is attempted. A practical test is therefore necessary. After a review of various suggestions and trials extending over several months, during which about 6 cwt. of bread was baked in eight different ovens, the Committee submit procedure for assessing the comparative suitability of a number of ovens for cooking purposes.

There are eighteen appendices to the report. The document will require an immense amount of study by those who are going to make effective use of it. The report itself is a reflection of the great difficulties encountered in attempting to produce standard tests for cookers; and the Committee do not suggest that what they have presented is the last word on the subject, or the tests represent finality. In an investigation of this sort, the results obtained during the experimental work inevitably produce further points which seem worthy of consideration and following up; at the same time a limit has to be set to the lines of investigation so followed, or the presentation of a report would have to be indefinitely postponed. These remarks apply with particular force to the bread-baking test. That part of the work had so many apparent lines of attack that to develop them all would have been impossible in the time at the disposal of the Committee. It is, however, believed that sound methods of differentiation between various ovens have been established; and should these, while satisfying the immediate need which led to the setting-up of the Committee, also prove of value as the starting-point towards something better, the Committee will welcome the advance, and feel gratified that their work has not been in vain. They acknowledge their indebtedness to the Gas Light and Coke Company for the accommodation placed at their disposal in which to carry out the work, for the loan of much necessary apparatus, and, not least, for the general assistance rendered by their staff in making alterations to existing apparatus, &c., as required from time to time during the progress of the work. Also to Messrs. John Wright & Co. and Radiation Ltd., to Messrs. R. & A. Main, Ltd., to Messrs. Wilsons & Mathiesons, and to the National Gas Council for the loan of two "Standard" cookers.

The report was introduced by Mr. C. F. Botley; and Mr. Forshaw gave a *précis* of it. The work is of very real importance, and the report is most welcome. It will enable valid comparisons to be made of the performances of different cookers, and will act as a reliable means of assessing the relative merits of gas and other fuels for cooking purposes. Only by strictly scientific methods can we combat with conviction the claims of competitors; and now we have here the necessary information to serve as an impenetrable shield against the shafts of loose statement. In view of the lateness of the hour, it was decided to conclude the business of the afternoon session without any verbal discussion on the report.

Benevolent Fund.

Before the technical work was resumed on Wednesday morning, there was a meeting of the subscribers to the Benevolent Fund. The proceedings were not long, and are reported fully elsewhere in this issue. Reference is made to the fund and its beneficent work here in order to emphasize points in the report. We need not utilize sentiment, or dilate on duty and responsibility, in order to urge the claims of the fund. Duty and responsibility are well appreciated if not always sufficient forces with some people to induce them to subscribe something from their pockets for the relief of the necessitous. The gas industry has its own needy ones whom misfortune or ill-health have overtaken; and in these days those who require financial succour, it must be recognized, should have it on a rather higher scale than was the case in the years prior to the war. Forgetfulness sometimes allows the point to be by-passed; but the Committee have recognized and acted upon it. Increases have been made in some of the grants; and the Committee suggest that the extra money should be adequately supplied by members of the Institution who have not hitherto subscribed. Moreover, the hand of death has deprived the fund of some of its old and staunch supporters—a circumstance which necessitates an earnest appeal for fresh help. The fund is administered by the Committee with care and discretion; and there is excellent protection through those members who kindly act as visitors.

Regenerative Coal Gasification System.

The whole of the sitting on Wednesday morning was occupied in listening to, and discussing, a paper by Mr. A. G. Lane, of Aylesbury, which was supplemented by useful communications by Dr. M. W. Travers, F.R.S., and Mr. F. W. Clark. The subject was the regenerative coal gasification system—a process invented by the two latter gentlemen; and which has been working at Aylesbury for some fifteen months. The plant has a rated capacity of 300,000 c.ft. Articles explanatory of the system and of the theory upon which it is founded appeared in the "Journal" in the autumn of 1923. As stated by Mr. Lane, the coal is transformed into gas in a single operation, leaving only ash, liquor, and tar as residuals. The carbonization of the coal is effected by internal heating—that is to say, by the direct transference of the sensible heat to the coal of gas passed through it at a sufficiently high temperature, and in the necessary quantity, to complete the process. The heat used is recovered regeneratively from the blow or waste gases. The plant and process are both described in the paper. The operation of the plant including the charging of the generator with coal is carried out by one man without assistance, and clinkering requires two men for about ten minutes. In considering the results, one has to keep prominently in mind the fact that, owing to the requirements for gas and coke for the fulfilment of contracts, the plant is only worked intermittently—for between four and eight hours a day. But Mr. Lane is satisfied. Experience indicates clearly that the shorter the standover period the better are the results obtained, and the smoother the working of the plant. Nothing has occurred which would in any way suggest that continuous working would give rise to difficulties. The plant ran for about eight months last year. Since January it has been in constant use, and the paper includes a summary of the results obtained from Jan. 7 to April 30. The therm yield for the four months' working amounted to 183 therms per ton, and the actual thermal yield available as town gas was 166 therms. This low result, says Mr. Lane, is due to the fact that on many Saturdays and Sundays the plant was run from between three and four hours, and to the practice of burning water gas in the plant as a means of speeding-up after the standover, and before carburetting. An interesting comparison is made of the thermal efficiency of the combined process of coal carbonization and the utilization of the coke produced in a water-gas plant and the efficiency of the complete gasification process. The author assesses the former as 46 p.ct., and the latter as 55 p.ct. When no oil is employed for enrichment, the gas produced in the regenerative gasification system has a calorific value of 360 B.Th.U., and is of the following composition: CO 28·0 p.ct., CH_4 9·5, H_2 49·0, C_mH_n 0·8, CO_2 5·5, and N_2 7·2. As to the cost of production into the holder, this is given for a gas of 420 B.Th.U. (*i.e.*, including oil enrichment) as 1·39d. per therm, or 5·85d. per 1000 c.ft. It will be agreed that this is a very low figure.

The paper is amplified by two communications—one from Dr. Travers, the other from Mr. Clark. Dr. Travers claims that the results of the Aylesbury plant under practical, if not ideal, conditions, as set forth in the paper, prove that the regenerative system as a method of completely gasifying bituminous coal is a practical proposition. He points out that in the plant four processes, each of which may be regarded as operating separately, take place—the carbonization, water-gas, regeneration, and carburetting processes—and he then deals with each stage in some detail. The communication makes interesting and instructive reading, and, what is more, shows that the entire problem has been tackled with the right attitude of mind—a desire to get at facts and not to rest content with any haphazard conclusions, to regard every phase scientifically, and to analyze the working in such a way that the results obtained will not depreciate in value when subjected to the searchlight of criticism. Mr. Clark confines himself to a description of the principles involved, and an outline of the advantages to be derived from the simplified process of complete gasification. He draws attention to the fact that in a vertical-retort plant which he recently examined, the space occupied by the flues surrounding the retorts, and the retort walls only (exclusive of all walls outside the flue space surrounding the retorts), is four times as large as the space occupied by the coal. By the direct application of heat to the coal, the whole of this flue space is avoided; and as the upkeep of this portion of a retort-setting constitutes the main item of cost in the repair bill for the retort plant, its elimination wipes out this cost. Such considerations as capital outlay, ground space, labour, and the handling of materials, all favour the adoption of a single-stage process.

A Few Features of the Discussion.

Many interesting points were raised in the discussion of the paper. Mr. Robinson, of Harrogate, referred to his complete gasification plant working there, in which they have obtained 174 therms of 425 B.Th.U. gas, 189 therms of 344 B.Th.U. gas, and 197 therms of 280 gas. He thought that the figure for the thermal efficiency of the regenerative gasification system—stated in the paper as 55 p.ct.—was low. Evidently the intermittent working accounted largely for this. Mr. Shadbolt, who for the last 4½ years has been in practical contact with another type of complete gasification plant said that with all inventions and new departures it appeared necessary to go through a circumlocutory phase, gradually becoming more and more complex, and then from the experience so gained, settle down to simpler methods of operation. We agree that simplicity is an ideal at which all should aim; but the carbonization and gasification of coal is in itself such a complex matter, that to attain a high efficiency often involves processes which, though simple to operate, are of necessity complicated; and in many cases real simplicity is not attended only with advantages. Among the benefits of complete gasification, the freedom from naphthalene troubles, which was mentioned by Mr. Shadbolt, is a factor of great importance. Dr. Lessing—who remarked how gratifying it was to see that more work of scientific worth and fundamental in character was being done to elucidate the problems with which practical men were confronted—made some interesting observations on the action of hydrogen in guarding the valuable hydrocarbons against thermal degradation. He welcomes the work of Dr. Travers and Mr. Clark, and thinks it will lead to great advances. Mr. George Helps asked Dr. Travers if he had considered the idea of using pulverized coal in connection with heat conservation in the production of gas. It appears that Mr. Helps thinks highly of the potentialities of coal in this semi-fluid state. Mr. Carr, of Stretford, also joined in the discussion. The basis of the Aylesbury plant, he said, was the carbonization of coal by the direct transference of heat. He has recently conducted some experiments on a plant embodying this method, and was impressed by the great degree of carbonization at low temperature which can be obtained by direct transference, and especially if mechanical means are employed for turning over the fuel. Many other features of interest were discussed, but space forbids their mention here.

The Gasification of Coke in Steam.

The Institution Gas Fellowship Report, by Mr. S. Pexton, Ph.D., M.Sc., and Prof. Cobb, was taken first at

the afternoon sitting on Wednesday. It concerned the gasification of coke in steam, with special reference to rates of gasification and the composition of the gas. In the previous report special attention was paid to the factors determining the production of ammonia and sulphuretted hydrogen. Rates of gasification with different cokes at several temperatures were also determined; but the composition of the gas was not studied in any detail. The present report is an amplification of the work, and investigations have been made on the composition of the gas and the amount of undecomposed steam as varying with temperature, the velocity of the gas stream, and the nature of the coke used. The report does several things. It shows that the dividing line between theory and practice is in reality non-existent, and it indicates the complex nature of the water-gas process. The truth of the latter remark is well exemplified in Table VII. of the report, where it is seen that, though 900° C. coke, bye-product coke, and 1270° C. coke are gasified at the same temperature (1000° C.) under the same conditions and with identical rates of steam supply, yet there is a wide variation in the CO-CO_2 ratio in the three cases. The dry water gas produced from the 900° C. coke contains 48·4 p.ct. of carbon monoxide and 1·1 p.ct. of carbon dioxide; the gas from the bye-product coke has a composition of 41 p.ct. of carbon monoxide and 6·4 p.ct. of carbon dioxide; while the amount of carbon monoxide in the gas produced from the 1270° C. coke is only 34·4 p.ct., and the figure for carbon dioxide 10·8 p.ct. This shows what an important factor is the physical structure of the coke. Indeed, cokes of similar chemical composition may give vastly different results, due to their varying "reactivity," or what may well be termed their "steam capacity." The reason that such a marked difference should result is not at first sight obvious, being bound up in the relative rates of coke gasification, which largely determine the concentration of undecomposed steam in the wet water gas, and this is the factor controlling the CO-CO_2 ratio. Should experiments be compared in which, instead of a constant rate of steam supply being employed, steam is supplied at such rates that the proportion decomposed is the same in all cases, the dry gas compositions are then similar, but the coke gasified in unit time, and the volumes of dry water gas produced in unit time are vastly different. To illustrate our meaning we will refer specifically to Experiments Nos. 18, 24, and 32. In these the percentage compositions of the dry water gas were respectively: CO 32·1, CO_2 12·1; CO 34·4, CO_2 10·8; and CO 36·0, CO_2 9.2. In these cases, however, the volumes of dry water gas were in the approximate ratio of 11 : 5 : 29. Another point of considerable interest is that dilution of the steam with nitrogen does not influence the percentage of steam decomposed at any given temperature. Here, then, we have another factor coming into play—that of turbulence and velocity. In a diluted state the gas stream moves more rapidly. Apparently this rapid motion, with its turbulence and its thinning or penetrating effect upon the gas film covering the coke (through which film gasification must be effected) compensates for the diminished time of contact. These results are in keeping with those obtained by Haslan, Hitchcock, and Rudow, though the experiments of these investigators were concerned not with dilution with nitrogen, but with alteration in the partial pressure of the steam. We could continue at length on this fascinating subject, but will content ourselves by stating that the report bristles with information of a vital order, and by stating that time spent on its careful study will be fully rewarded.

Points of General Importance from the Discussion.

Prof. Cobb introduced the report to the meeting; and his remarks are published *in extenso* in later columns. Mr. Thorman, in the discussion on the Twelfth Report, mentioned that his observations on the working of a waste-heat boiler had brought out the fact that, though in one case several tubes were stopped-up, thereby reducing the heating surface, the amount of steam evaporated per pound of fuel consumed in the generator remained constant, showing that the increased velocity had compensated for the reduction in heating surface. Prof. Cobb recalled this, and drew an analogy to the compensating influence of increased velocity in the production of water gas—an effect to which we have referred in previous remarks. Dr. Pexton then gave a *précis* of the report, which he delivered in a clear and lucid manner. An interesting point was raised by Mr. Madden, who subscribed to the subsequent discussion. He asked as to what size of coke was most suitable for a water-gas generator. This is a subject on which there is not a great deal of information; and it is felt that study in this direction would yield fruitful results. Perhaps this suggestion which we now make will be taken up. Dr. Travers made the interesting observation that the CO-CO_2 equilibrium at the top of the fuel bed pointed to a much higher temperature than existed there, and corresponded to the maximum temperature of the reaction. He suggested that this might be due to the freezing of the equilibrium in passing through the cooler layers. Dr. Parker, however, did not agree that this afforded a sufficient elucidation, and emphasized the fact that, though the "freezing" theory might explain the CO-CO_2 ratio if no steam were present, the effect of the partial pressure of the steam must be taken into consideration. This factor, he thought, provided a more adequate explanation. Dr. Pexton replied to the several queries raised; and the concise manner in which he did this was greatly appreciated by the members.

Silica Gas Retorts.

The next item on the programme was a paper on "Silica Gas-Retorts" by Mr. W. Emery, of Stoke-on-Trent. It is certainly true that among the literature on the subject of silica refractories, but little can be found which is of help to the hard-worked provincial gas engineer; and this contribution—which in brief is a compilation of information as to the working of a number of installations in this country where silica retorts are in use—is one of considerable utility to the practical man who may be faced with the necessity of reconstructing his plant, and who is naturally anxious to employ the refractory which will prove to be the most efficient and economical when adopted at his works. The question as to whether silica or siliceous refractories give the best results is still an open controversy, and though the paper by Mr. Emery is more of the nature of a review than a positive expression of opinion, it is of definite value. He mentions that the published data concerning the thermal conductivity of refractory materials do not reveal any striking differences in the values for silica and fireclay up to 1000° C., so that in carbonizing plants where relatively low temperatures are employed, there is little to choose between silica and fireclay on the ground of thermal conductivity alone. The thermal conductivity at a specified temperature is determined by the product of the heat capacity and diffusivity; and since the heat capacity of silica is lower than that of firebrick, the diffusivity of the former must be greater to obtain the same conductivities. Below 1000° C. this increase in diffusivity is not generally noted, which leads the author to believe that, in general, firebrick is probably the better conductor of heat at lower temperatures. A summary of available data, however, suggests that heat transfer is more rapid in silica at the high temperatures now in use—viz., 1300° to 1400° C. Mr. Emery has examined a large number of refractories of all types after they have been used in heating units, and from his observations concludes that there is less alteration in the porosity of silica goods during use in gas installations than is the case with fireclay materials. He draws attention to the development which has taken place in the manufacture of silica refractories. At the present time the average grain size is less, the mass is more homogeneous, and the firing more satisfactory. This is all to the good. It must be admitted, of course, that the manufacture of fireclay and siliceous retorts has not reached finality as regards improvement; and possibly competition will stimulate the manufacturers of this type in the direction of improved texture and the development of a refractory which, while not remaining rigid at the highest temperatures, will be more suitable than silica for the engineers who prefer to carbonize at moderate temperatures.

Certain classes of refractories remain fairly rigid under load at high temperatures not far removed from those at which breakdown occurs; other types deform at relatively low temperatures. Silica belongs to the first class. As regards abrasion, the silica retorts which have been inspected by the author have withstood scouring action very well. Mr. Emery points out that, though it is admitted that moulded fireclay retorts exhibit a tendency to crack after a comparatively short life, as compared with segmental silica retorts, this fact cannot be accepted as evidence that silica is more resistant to cracking than fireclay, and in order to obtain a real criterion, segmental or moulded refractory

material of each type should be compared. The effect of thermal changes is dealt with somewhat fully, and the opinion is expressed that it is advisable to make use of admixtures of catalysts such as lime, pyrites, &c., in order to ensure more complete conversion of silica into tridymite, with its accompanying reduction in permanent expansion. Mr. Emery concludes his paper by giving the results of his visits to several plants, including vertical-retort installations of various types. There is also an appendix on the microstructure of retorts described in the paper; this being contributed by Mr. A. Scott, D.Sc., M.A.

A case of an exceptionally good fireclay material is quoted. This is at Keighley, where it is stated that fireclay retorts have operated for a working period of 2660 days, carbonizing 20-cwt. charges in twelve-hour periods, and with the abnormally high working temperatures (for fireclay) of 1370° to 1420° C. Judged by the usual standards, this fireclay is exhibiting extraordinarily good qualities; and the author suggests that a possible explanation lies in the fact that the maintenance of porosity at elevated temperatures may allow the infiltration of carbon to proceed to such an extent that the retort may become a carbonized clay substance which possesses a higher refractory value than normal clays. Regarding jointing, mention is made of a patent taken out by Messrs. Robert Dempster & Sons, Ltd., in which they claim that, with the use of plastic siliceous clay (having an 8 p.ct. drying contraction) in the joints, the thermal expansion of silica between 200° and 580° C. is gradually absorbed.

Mr. Emery dealt only with the salient features of his paper, and then spent some little time in describing the exhibits of retort materials, the micro-photographs of which are given in the appendix.

Refractory Materials.

The Refractory Materials Joint Research Committee next claimed consideration for their report, which was submitted by Mr. J. P. Leather, the Hon. Secretary to the Committee. The report is short; but it is accompanied by a series of communications recording work done by the British Refractories Research Association, and to the publication of which permission has been given by the Committee of the Privy Council for Scientific and Industrial Research. These communications, it is believed, will help British manufacturers to meet the demands of the gas industry for improved material. As the Committee say, much more research is needed to produce results in the form of goods capable of enduring the high temperatures towards which practice is tending; and it is the view that the Association are now getting into more effective work.

One of the communications is by Mr. W. J. Rees, B.Sc., on the storage of silica refractories. The tests show definite indications that the loss in strength of silica bricks exposed to weather is in part due to a slight degradation of the bond by hydration and solution in water, as well as to the physical effect of frequent wetting and drying. The tests also show that there is little or no distinction in the behaviour of coarse and fine textured briquettes; but in both cases the briquettes burned at the higher temperatures were more resistant to water attack. The loss in strength was in all cases more marked with long exposure to moisture. The finding is emphatically as to the need for suitable protection of silica bricks during storage, as they suffer considerably by exposure to weather.

The first part of an investigation by Mr. A. J. Dale on the relation between composition (chemical and physical) and refractoriness under load represents a large amount of work, although the research is still incomplete. But there is evidence that for a straight clay the rate and amount of subsidence under load at a fixed temperature is related, within limits, to the proportion of grog—*i.e.*, the larger the proportion of grog, the more rapid the subsidence and the greater its amount.

A note by Mr. S. R. Hind, B.Sc., appears on purifying clays by sedimentation, but the work so far in connection with this investigation is purely of a preparatory nature. But it is hoped it will lead to improvements in the methods of manufacture.

Then there is research, by Messrs. Hugill and Rees, on the effect of repeated burning on the structure of properties of lime-bonded silica bricks. This shows that prolonged "soaking" of the bricks in the kiln increases their strength by completing changes in the allotropic form of the silica, which should not be left to occur when embodied in the gas-works furnace.

Dr. J. W. Mellor contributes the first part of a paper on some causes of the variation in the sizes of refractories. This, as the Committee say, is a subject which is of particular importance where bricks and blocks are used to form gastight joints in retorts and regenerators. The conclusions are: (1) The maturing temperature of firebricks is not a fixed point to be decided by a specification applicable to all fireclays; rather it is a temperature peculiar to each clay. (2) The best temperature for maturing a firebrick made from the ordinary types of fireclay is that temperature at which the contraction-temperature curve has flattened, so that any further rise of temperature produces insignificant changes in volume when the firebrick is heated to the highest temperature at which it is likely to be used. (3) If the contraction-temperature curve has not flattened at the top temperature of the kiln, there will be greater variations in the sizes of bricks than where the bricks are fired at the temperature at which the curve has flattened.

Reverting to the report, the Committee say that, while for some purposes—*e.g.*, the walls of retorts and the interior of regenerators—a higher conductivity material is desired, there has of recent years been an increasing demand for a heat-resisting material of low thermal conductivity to reduce the loss of heat from settings. This is especially emphasized where a use for the surplus heat is being found by waste-heat boilers. In this connection, there are communications by Mr. A. T. Green, representing a large amount of work on the conditions affecting the thermal conductivity of firebrick. This was one of the directions in which the Institution requested that research should be conducted.

Consensus of Opinion in Favour of Silica.

Mr. W. B. Leech, Engineer of the Beckton Works of the Gas Light and Coke Company, in the discussion, drew attention to the advantages and disadvantages of silica, saying that the former outweighed the latter. It has been definitely proved at Beckton that silica retorts have a longer life than have those made of fireclay; some retorts have been in continuous operation for 4000 days. Also, by the use of silica, the scurfing period is reduced by one-third; and it is unnecessary—in fact, dangerous—to use scurfing tools. Careful consideration should always be given to jointing; and Mr. Leech is of the opinion that when properly fitted the tongued and grooved joint is preferable. He expressed surprise that at Keighley the working life of the fireclay retorts was 2600 days. At Beckton a good average service was 500 days. Of course, the size of the coal influences this. Mr. Gill, the next speaker, thinks that the days of the ordinary fireclay retort are past, and that in future fireclay will only be employed for the cooler portions of the setting. He said that he had examined the retorts at the Keighley works, and they are built of siliceous material. The remarks of Mr. W. S. Morland, of Gloucester, were for the most part confined to the important question of efficient jointing; and he mentioned that dust is apt to accumulate in joints when the setting is let down. This interferes with the proper contact of the faces when the retort is again heated-up, with the result that leakage occurs. In his opinion, a good deal is to be said for fireclay retorts. Settings erected at Gloucester in 1915 give 70 therms per ton of coal carbonized. Mr. Toogood said that the gas industry as a whole owes a debt of gratitude to the Gas Light and Coke Company. He then described briefly the improvements in horizontal-retort design which had been made recently by Messrs. Robert Dempster & Sons, Ltd. Carbonizing temperatures to-day are often maintained at 2500° Fahr. To withstand these temperatures, 95 p.ct. silica refractories are used; and as the expansion of silica is greater than that of firebrick, increased temperature and expansion render more difficult the stability of the producer arch. In the new form of setting, the arch is reinforced in such a manner as to provide a superimposed or inverted buttress placed where the weight and expansive forces are likely to cause failure. The producer arch is surmounted by an elliptical arch, so that practically no dimension exists between the legs of the combustion-chamber arches. By combining the keystones of both the producer arch and the superimposed series of combustion arches, the advantages of added strength, increased stability, and ability to withstand expansion strains, are obtained. This construction

enables the elliptical combustion-chamber arches to be designed as complete ellipses of the fullest major and minor axes permissible by the particular grouping of the retorts. The joints are of the tongued and grooved type.

The observations of Mr. Middleton, of the Consett Iron and Coal Company, are of great interest. He has recently erected coke-ovens of a capacity of 1000 tons of coal per day, built entirely of silica; and he has made a comparison with older plants in which an 80 p.ct. silica refractory is used. He has found that in the silica ovens the time of carbonization is reduced from 27 hours to 16 hours. The ovens themselves are 3 in. less in width in the new setting; and allowing a reduction in coking time of 1 hour per 1 in. reduction in width, he assesses the reduction solely due to the use of silica as six to seven hours. Moreover, this has been effected without any increase in working temperature. With higher temperatures, the conductivity would be increased; and it is possible to look forward in the future to a 40 p.ct. greater output by the employment of silica in oven construction. Not only this, there is also less variation in the raw material, and shapes of great accuracy can be assured. Mr. Rhead, of Birmingham, also took part in the discussion, emphasizing the importance of good cement for jointing purposes.

Dry Coke and New Gas-Works at Garston.

One can learn much from the interchange of experiences in engineering matters. In every scheme all manner of details have to be taken into consideration; and papers of the type submitted by Mr. R. E. Gibson, of Liverpool, are of great practical value. The substance and animation of the discussion which followed its reading is proof sufficient of the interest aroused; but more as to this later. The paper deals with the reasons for the adoption of the various kinds of plant and the different forms of construction employed in the erection of the new gas-works at Garston, and gives a few particulars of the results obtained. In 1919, states the author, the proportion of water-gas plant to coal-gas plant was high—being almost half-and-half—and the cost of production of water gas per therm was much greater than that of coal gas. It was therefore decided to reduce the proportion of water-gas plant by installing coal-gas plant. A further strong reason for the adoption of coal-gas plant was the fact that the Garston Works up to that time was purely a water-gas station; the whole of the coke required being supplied from the other coal-gas works, involving great expense in carriage and handling charges. By arranging for the coke to be made at Garston, it was estimated that the saving on this item alone would be £13,000 per annum. The decision arrived at was to erect horizontal plant, and to produce rich coal gas by using good coal and some cannel. The retorts—24 in. by 18 in. by 22 ft. long, of ⏢ section—were arranged in "tens;" and each retort is capable of carbonizing 35 cwt. of coal per day. It is of interest to note that the method of coke-quenching adopted was the inclined bench in common use in coke-oven practice, and gradually spreading in gas-works equipment. Opportunity was taken, however, to make experiments in the dry cooling of coke. We agree with the author when he suggests that the time is not far distant when consumers of coke will become alive to the fact that every pound of moisture in the coke not only takes the place of a pound of fuel, but has to be driven-off at the expense of a further quantity of fuel before useful work can be done. Mr. Gibson is of the opinion that there are no insuperable difficulties in the way of producing from horizontal retorts coke entirely free from moisture, while at the same time conserving the heat of the red-hot coke. He then proceeds to describe the Garston installation, which produces absolutely dry coke of a bright silvery-grey colour, which has a higher calorific value, and which burns more freely in an open fire. The cost of obtaining the improved value works out at 1s. 3½d. per ton. Suppose a consumer pays 37s. 6d. per ton delivered for coke containing (say) 20 p.ct. of moisture, he could afford to pay 10s. 8d. more for the dry coke, without incurring any loss in fuel value. Of course, when the gas undertaking sells one ton of moist coke containing (say) 20 p.ct. of moisture, it really receives 32s. 6d. for 0·8 ton of coke, or in the case of coke containing 10 p.ct., 0·9 ton. These prices are equivalent to 40s. 7½d. and 36s. 1d. respectively per ton of dry coke; and to obtain the same return, these prices would have to be obtained *plus* the extra cost of producing the dry coke. The consumer would be 2s. 6½d. to the good if he paid 8s. 1½d. more for dry coke than for coke containing 20 p.ct. of moisture, while he would be 1s. 1d. to the good if he paid 3s. 7d. more for dry coke than for coke containing 10 p.ct. of moisture. It may be said, therefore, that the production and sale of coke in an absolutely dry state is a sound proposition, provided the customer is made to appreciate its superior value.

It is not possible here to make an adequate summary of the paper, but before we turn to a few remarks on the salient features of the discussion, mention may be made of some other points of interest. One of these is that, to avoid corrosion and extend the life of the gravity-bucket conveyor used for handling the purifying material, Mr. Gibson has made a trial with buckets coated with vitreous enamel. This adds about 50 p.ct. to the cost of the buckets; but it is believed that the life will be increased at least fourfold. Another matter of interest is the method adopted at Garston for dealing with the gas in the purifier before the lids are lifted for charging the oxide. Then there is a new washer of the horizontal type erected a year ago by Messrs. W. C. Holmes & Co., Ltd., for the extraction of naphthalene. This is the first Holmes washer in which the case has been erected of mild steel with welded joints. This method of construction has certain advantages over cast iron; it is lighter in weight and less in first cost. The engine is housed in a circular extension of the washer itself. As to the working results of the entire plant, an average yield of 80 therms per ton was maintained last August; while the average from July, 1922, to December, 1923, was 73 therms. In each case the calorific value of the gas was over 570 B.Th.U. per c.ft. These are excellent results, and reflect great credit on Mr. Gibson and the staff at Garston.

An Animated Discussion.

The paper was responsible for a discussion of length and great interest. Mr. Leather strongly advises the production of dry coke. He has recently been to Holland to investigate the Sulzer coke-cooling plant, and thinks highly of it. By the adoption of such a system, one obviates the chief cause of discomfort to the workers, and also the main promoter of corrosion—the effect on the ironwork of the acid-laden vapours rising from the coke-quenching process. Not only this; there is proper utilization of what is otherwise waste heat, and this is reflected in a saving in the boiler fuel. He has no doubt that customers could be educated to the advantages derived from the use of dry coke. Mr. Johns, of Swansea, is of the same mind, and is determined to adopt a coke-cooling plant of the Sulzer type if this is possible in the future. Regarding the refractory to be used for retorts, he has no hesitation in adopting silica. Of course, the argument was not all one-sided. Mr. Morland, of Gloucester, suggested that the expenditure of the process did not stop at the actual cooling stage. If the coke had to be stored, and at the same time maintained in an absolutely dry condition, the buildings would have to be weather proof. The Sulzer system, he thinks, is still in the experimental stage, and not as yet a practical proposition. Another point he raised referred to the adoption of concrete purifiers. The structures were useless if they had to be dismantled, and the actual cost of breaking-up had to be considered. He cited the case of a concrete ship launched near Gloucester which actually cost more to break up than it did to build. Mr. G. M. Gill held that if due care were exercised in coke quenching, there was no reason why the moisture in horizontal retort coke should be excessive. It is well within the bounds of possibility to produce a coke with a constant moisture content not exceeding 4 p.ct.; and the little extra work and supervision entailed will be well repaid by an increased demand for the better coke. Part of the discussion centred round the relative merits of horizontal and vertical coke. Mr. Jackson, of Neath, said that in his district there was a much greater demand for vertical coke. He also pointed to the incongruity of having specifications for gas, tar—in fact, nearly everything with which they had to deal—and no restrictions whatever on the quality of coke. On the other hand, Mr. Cranmer, of Willenhall, who suggested that the provision of a special coke-cooling plant was an unnecessary expense, stated that he had found equal demand for horizontal and vertical coke. Mr. J. G. Tooms, of Christiania, has recently toured Germany and Austria; and from his experience he has come to the conclusion that economical considerations will probably prevent any extensive adoption of the Sulzer process. In

Mannheim, for instance, there is difficulty in utilizing the steam produced, while the waste gases from the setting are escaping at 600° C. Mr. Tooms stressed the necessity for eliminating as far as possible any nuisance arising from obnoxious smells in the gas-works process. Continuous verticals, he said, possessed this admirable advantage. The whole question was of importance for the future goodwill of the industry. Mr. Rhead questioned the accuracy of rotary meters; but Dr. Parker said that, if the gas were clean, this type of meter gave records equal to those obtained by the ordinary wet meter. The gas must be clean, otherwise big discrepancies arose. For example, a deposit of naphthalene of a thickness of only $\frac{1}{10}$ in. on a 4-in. tube leading to the vane would cause the meter to read 10 p.ct. fast. Mr. H. Davies, of Chesterfield, and Mr. D. Irving, of Bristol, also subscribed to the discussion. Mr. Gibson, in replying, said that the whole of the dry coke produced at Garston was used in the water-gas plant. At Linacre, however, they find no difficulty in obtaining a higher price for the dry coke.

Closing Business.

The communication by Mr. Gibson was the last to be presented, and the President then announced the result of the ballot. Loud applause greeted the information that Mr. J. Ferguson Bell, of Derby, had been elected President. Mr. C. F. Botley, of Hastings, was elected Senior Vice-President, and Mr. John Wilkinson, of Nottingham, Junior Vice-President. Messrs. C. Dru Drury (Sunderland), Douglas H. Helps (Reading), Percy N. Langford (Coventry), and John Terrace (South Suburban Gas Company) take seats on the Council.

Mr. Ferguson Bell in his acknowledgment left no doubt of his high appreciation of the honour conferred upon him. He said that Mr. W. Woolley, the Chairman of the Derby Gas Light and Coke Company, on behalf of himself and his co-Directors, had extended to the members of the Institution an invitation to visit Derby next year. Mr. Bell suggested that they should hold the annual meeting in London, but hoped that on the last day of the meeting the members would visit Derby.

A pleasing innovation was the presentation by Mr. Ferguson Bell, on behalf of the Council of the Institution, of a certificate to the President on the completion of his year of office. It is intended that this token of regard shall commemorate the services of past and future Presidents.

The conference then concluded with votes of thanks to the Institution of Electrical Engineers for the use of their building for the meeting, to the President and officers of the Institution, and to those responsible for the reports and papers. And so ended a highly successful meeting full of interest and animation which will long remain in the memory of those who were fortunate enough to attend.

SOCIAL EVENTS.

Reception by the President and Mrs. Tagg.

A brilliant function took place on the Tuesday evening, Mr. and Mrs. Tagg holding a reception at the Connaught Rooms, Great Queen Street. No fewer than 545 guests attended, thoroughly enjoyed themselves, and carried away memories of perfect arrangements and the charm of an ideal host and hostess. Having experienced the expanse and splendour of the City Hall, Belfast, we were somewhat apprehensive of the water-coloured confines of "Prince's;" and so it was with particular gratification that we learned of Mr. Tagg's decision to have a change at the Connaught Rooms, and the magnificent Hall in the adjoining headquarters of the Freemasons. The move was well-advised and very popular; indeed, it is not cooling even now to picture that large assembly at the former rendezvous on such a June evening as smiled upon the proceedings.

The President and Mrs. Tagg received their guests at the head of the main staircase—a task the severity of which was not reflected in the bright welcome which awaited all. Mrs. Tagg carried a beautiful bouquet of pink carnations. We shall not attempt even to head a paragraph "Those present included," for so many well-known faces were there. It must suffice to mention the following representatives of the industry's chief activities: Mr. J. Ferguson Bell (President-Elect of the Institution of Gas Engineers), Mr. C. F. Botley (Senior Vice-President), Mr. John Wilkinson (Junior Vice-President), Mr. James Paterson, Mr. W. E. Price (Hon. Secretary), and Mr. W. T. Dunn (Secretary). Mr. Ernest J. Fottrell (Joint Manager, National Gas Council), Mr. Sholt S. Ogilvie (Joint Manager), and Mr. W. J. Smith (Secretary). Mr. F. W. Goodenough (Executive Chairman) represented the British Commercial Gas Association, and Mr. W. J. A. Butterfield the Gas Referees. The Chairmen of the different sections of the Society of British Gas Industries were there, including Mr. J. Wilfrid Drake (the Chairman of Council), and Mr. F. C. Tilley (his immediate predecessor in that office); and we recognized Mr. R. W. Edwards (Vice-Chairman of the Gas Companies' Protection Association). Invitations had been accepted by Mr. Rae P. Normand (W.M. of the Evening Star Lodge), with whom we must mention Mr. W. A. Surridge, by Mr. Ernest West (W.M. of the Northern Star Lodge), and by Mr. R. J. Milbourne (W.M. of the Murdoch Lodge). Prof. Arthur Smithells and Prof. John W. Cobb, and Sir Arthur Duckham, K.C.B., are figures in every representative gathering of the gas industry; and well known among the company were Sir Richard Threlfall, K.B.E., F.R.S., of the Fuel Research Board, Alderman Fell, J.P., O.B.E., of Nelson, the Mayor of Preston, and the Mayor of Mossley.

All found the reception a delightful interlude in the serious work of the early part of Institution week, and the scene was one of great animation and enjoyment. Excellent music encouraged young and old alike to dance, and the warmth of the evening merely enhanced the universal approbation of the excellent catering arrangements and the beautifully decorated lounges. Mr. and Mrs. Tagg are to be congratulated.

The President's Luncheon.

The President's luncheon on Tuesday was a highly successful function. There were several guests identified with the gas industry—directly or indirectly. Here nothing more than a note of the event is required, as an extended report of the speeches made on the occasion is given in succeeding columns.

The Council Entertains.

As on previous occasions, the luncheon on Tuesday had its counterpart on Wednesday, when the Council of the Institution entertained the President and Mrs. Tagg to luncheon at the Savoy Hotel. Though the function is "unofficial" both in letter and in spirit, we are permitted to make brief reference to it. Mr. J. Ferguson Bell was in the chair, supported by Mr. C. F. Botley; and Mrs. Bell and Mrs. Botley were there. Mrs. W. E. Price unfortunately could not accompany the Hon. Secretary; but Mrs. W. T. Dunn was there with her husband. Mr. Thomas Goulden was abroad, and Mr. J. D. Smith unable to be present, but otherwise the Council was very fully represented. The unofficial character of a short toast-list in no way detracted from the heartiness which accompanied the good wishes tendered to the President, the President-Elect, and the ladies. Mr. Ferguson Bell, in proposing the first of these, attributed to Mr. Tagg the passing of the thousand mark in membership of the Institution, as well as the record attendance of over 700 at the first day's meeting. The President dwelt on the friendship and the assistance he had met during his year of office, and paid a tribute to that "experienced and sagacious adviser," Mr. W. E. Price, and to Mr. Dunn, whose "article of faith was that the industry should maintain its position." Mr. James Paterson wished the President-Elect a happy year of office, which toast was graciously acknowledged by Mr. Ferguson Bell. "The Ladies" was ably proposed by Mr. W. J. Smith, and charmingly acknowledged by Mrs. Tagg; and Mr. Price and Mr. Dunn received their due before the party turned again to the more serious business of the afternoon session.

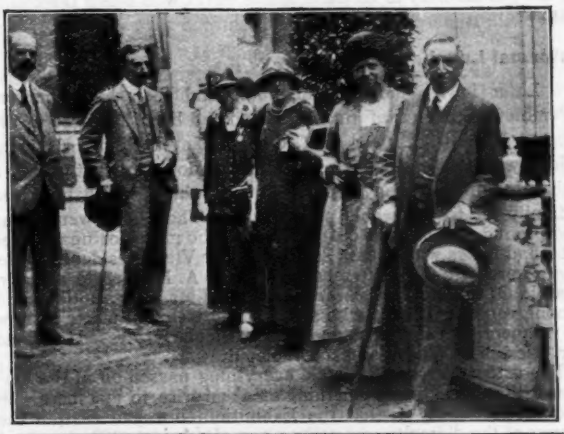
Visiting the Cenotaph.

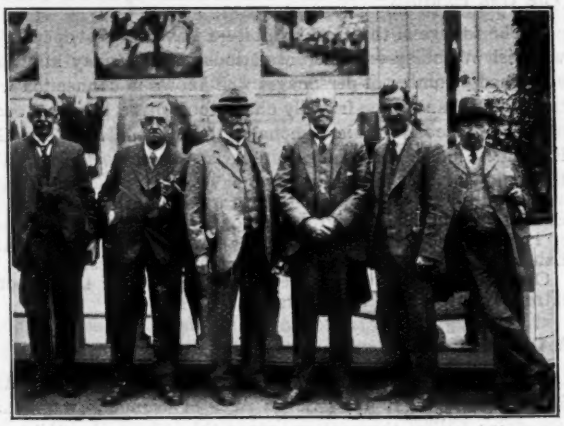
During the final moments of the last business session on Thursday morning, a beautiful wreath was brought into the theatre of the Institution of Electrical Engineers, and placed in full view of all the members, who rose and remained standing in silence for some seconds. Then the President explained that this token of respect was the outcome of a felicitous suggestion made by Mr. C. V. Bennett, of Rochester, that members visiting Paris and members remaining in London should act in unison, in offering tribute to those who had given their lives in the Great War. Arrangements had been made that the party visiting Paris should at 11 o'clock on Friday morning pay respect to the brave Frenchmen who had died in the war by placing a wreath on the grave of the Unknown Warrior; and the proposal of Mr. Bennett, which met with such ready acceptance, was that, at the same time, at the Cenotaph here, those who had remained in town should similarly commemorate the sacrifice of our own countrymen.

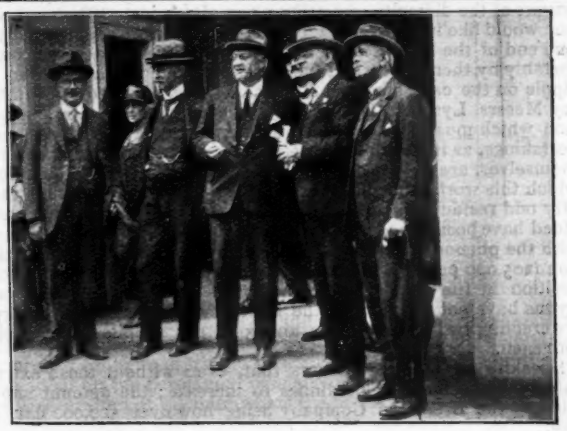
Accordingly, on Friday morning, in the midst of life and movement—for the centre of Whitehall must be one of the busiest spots to be found anywhere—there was to be seen a group of earnest men whose thoughts for the moment were only of death. The Cenotaph is a perpetual reminder both of what we have lost and what we have gained. But as 11 o'clock struck, and Mr. James

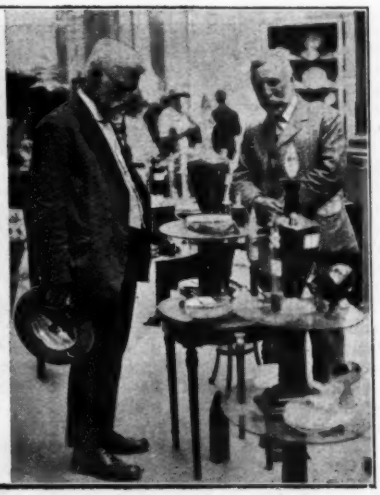
[Continued on p. 74.

SOME OF THE INSTITUTION VISITORS AT THE GAS EXHIBIT ON FRIDAY.









FRENCH GAS CENTENARY NUMBER OF THE "JOURNAL."

An Appreciation.

The preparation of a special number of the "JOURNAL" to record the centenary of gas supply in France and the Jubilee of the Société Technique de l'Industrie du Gaz en France was conceived by us with the dual object of being of assistance to our own engineers in the visit to Paris—at the same time adding interest thereto by briefly sketching French gas history—and of representing to our French friends the very close bonds which tie the professions of the two countries.

Comments which have reached us by word of mouth and letter since the issue of the "JOURNAL" for June 18 lead us to believe that our objects were achieved; and we shall be pardoned for acknowledging in our columns the gracious reference made by the President of the Institution at the banquet last Friday, and the letter of appreciation addressed to us by M. Rouland, the President of the Société Technique. A translation of M. Rouland's letter follows:

> I have just received the copy of your "JOURNAL" for June 18, which you were good enough to address to me personally. On behalf of my colleagues on the Centenary Committee I have to thank you for the extremely cordial manner in which you have brought our celebrations before your readers. You have, moreover, in noteworthy fashion borne witness to the bonds of affection which unite us, in publishing French translations of several articles.

Paterson (then the Senior Vice-President) advanced, and reverently placed the wreath at the foot of the monument, the minds of those who looked on—and who included Mr. C. F. Botley (the newly-elected Senior Vice-President for 1924-25)—were filled only with remembrance of what we have lost. The well-chosen inscription on the wreath, indeed, found an echo in the hearts of all present: "In undying appreciation of the heroism and sacrifice of the sons of the gas industry in all parts of the world, who heard the call to arms."

Informal Luncheon at Wembley.

Later in the morning, members and their ladies met at Wembley, where an informal luncheon had been arranged in the Regent Restaurant, near H.M. Government Building. Here at mid-day a party of about two hundred sat down to what proved a delightful meal served at small round tables, which imparted a family air to the whole proceedings. Those who were alone soon found friends, and ceased to envy the more fortunate ones who had ladies with them. At the Senior Vice-President's table, there were with Mr. Paterson, Mr. W. J. A. Butterfield and Dr. Harold G. Colman. Elsewhere one noted Mr. C. F. Botley; and among very old friends who are unfortunately not met with now so frequently as formerly, one was particularly pleased to greet Mr. Alexander Wilson and Mr. James Stewart.

The smoothness with which everything passed off at the luncheon may have been something of a surprise to members who had not previously visited the Exhibition, but had read in the papers of the difficulty of getting a cup of tea just at the moment one would like it. The party of two hundred were shepherded to one end of the huge Regent Restaurant, where they were comfortably by themselves, and their presence did not cause even a ripple on the calm surface of business there. Indeed, at Wembley Messrs. Lyons & Co. have achieved a triumph of organization which must be the wonder of many other big business undertakings, as it certainly is of people who, while not caterers themselves, are able to understand something of the difficulties which this world-famed firm are up against. It is true that the fifty odd restaurants and cafés which were in the first place provided have been found inadequate at "peak load" periods—as, with the phenomenal crowds that are now flocking to the Exhibition (205,000 people were there on Saturday), any practical proposition in the way of accommodation must be; but Messrs. Lyons have not yet reached the limit of their resources. They are erecting two big new cafés, and 3-in. gas supplies are going into each.

Speaking of gas, one gathers that, even without these extra cafés, the consumption continues to increase; the amount supplied by the Brentford Company being now over 560,000 c.ft. a day.

A Telegram to Paris.

During lunch, Mr. Paterson wrote out the following telegram which it was decided should be despatched to Mr. Samuel Tagg, the President, at Paris: "Members assembled at Wembley send hearty good wishes for most enjoyable visit.—Paterson."

All Roads Lead to ——.

It was still quite early when luncheon was finished, the great heat of preceding days had given place to a more invigorating atmosphere, and with a long and pleasant afternoon before them members scattered in various directions, for the subsequent proceedings were as informal as the luncheon. Surely there is no one so difficult that he cannot satisfy himself at Wembley! Some went on to the Gas Exhibit, and then perhaps to the Amusements Park; while some went to the Amusements Park and then to the Gas Exhibit. There were still others no doubt who—well, went to the Amusements Park. At any rate, as was bound to happen in so large a place, amid so vast a concourse of people, many of those who parted on leaving the restaurant did not see one another again for the remainder of the day. But those one did come across—and there were many happy meetings of old friends in the "Gas Man's Mecca"—left a strong impression on the mind that the visit had afforded much enjoyment to the participants.

The Gas Exhibit.

The lounge of the Gas Exhibit—a haven of rest open to all who visit Wembley—at different periods during Friday afternoon contained a number of personages well-known in connection with the industry, and some friendly chats took place between occupants of the comfortable armchairs there provided. The Gas Exhibit is, indeed, becoming quite a well-known *rendezvous*. The Bath and County Club are going to have a day at Wembley—and have, entirely on their own initiative, arranged to meet at the Gas Exhibit, as being both central and comfortable. The Institution of Heating and Ventilating Engineers, who last week visited the Exhibit, of course found a great deal there to interest them.

Opportunities offered themselves at intervals of taking some extremely interesting snapshots.

A Question of Age.

Was it a gas engineer who, after gazing earnestly at Age Six (Middle Age), in the "Seven Ages of Woman," was heard to mutter: "Why, there was no gas in the 'Middle Age'!"

MR. JAMES PATERSON, M.A., DEPOSITING THE WREATH AT THE CENOTAPH.

A Tribute to Gas.

Remarkable proof of general recognition of the multifarious uses of gas is to be found in the frequent query put by visitors to the "Old Age" sitting room: "Is the gramophone run by gas?"

Some Jottings.

Friday will be famous in the Exhibition annals for at least two events—the visit of the Institution of Gas Engineers, and the passenger-carrying start of the long-promised "Never Stop Railway."

There have been complaints lately—and it must be admitted not altogether without justification—of the quantity of litter to be seen strewn about the grounds; but, as a matter of fact, one of the big jobs of the Exhibition has been dealing with the rubbish. Vast quantities of it are collected, and have to be disposed of. Here, once again, gas has come to the rescue. To the Exhibition authorities' own incinerator a 3-in. main has been laid down, and by means of some specially large size burners the whole of the rubbish collected is now being consumed.

The visit of the Institution was preceded, on Thursday, by a small fire in Malaya, where an electrical short-circuit resulted, it is stated, in the burning out of a large portion of the kitchen. Of course, gas is used for cooking there; electricity being utilized for lighting purposes only.

It is hoped that many of the Institution members were able to remain on Friday evening late enough to see the beautiful illumination of the grounds. Here the profusion of many-coloured lights and the surrounding white and grey buildings make up a scene that will long remain in the memory.

THE CELEBRATIONS IN PARIS.

Our account of the events associated with the visit of the President and Members of the Institution to Paris in connection with the Gas Supply Centenary Celebrations in France, and the Jubilee of the Société Technique du Gaz, appears at the end of the proceedings at the Meeting of the Institution. We may also remind readers of the special articles on Gas Supply in France, with a descriptive report on the Gas Exhibition, which appeared in our issue for June 18.

THE PRESIDENT'S LUNCHEON.

At the close of Tuesday morning's session, a large party, including the members of the Council, Association Presidents, and a number of others who are well known and highly respected by all connected with the gas industry, were the guests of the President at luncheon in the Savoy Hotel. Mr. Samuel Tagg, of course, was in the chair, and at the top table with him there sat: To his right, Mr. H. C. Honey (Gas Administrator, Board of Trade), Mr. W. H. Patchell (President of the Institution of Mechanical Engineers), Dr. Charles Carpenter, Mr. A. Abbott (Board of Education), Sir Arthur Duckham, K.C.B., the Mayor of Preston (Alderman F. W. F. Mathew), Mr. F. W. Goodenough. To his left, Sir Henry P. Maybury, K.C.M.G., C.B. (Director-General of the Roads Department), Sir Charles L. Morgan (President of the Institution of Civil Engineers), Prof. Arthur Smithells, Dr. C. H. Lander, Mr. W. Woolley (Chairman of the Derby Gas Company), Mr. J. Wilfrid Drake (Chairman of the Society of British Gas Industries), and Prof. J. W. Cobb. Among Past Presidents of the Institution noticed were Mr. James D. Smith and Mr. Thomas Hardie. The toast of "The King" having been honoured at the call of the Chair,

The CHAIRMAN submitted "The Board of Trade and the Ministry of Transport," remarking that the equanimity with which people in this country received a change of Government was, he thought, due to the reliance they placed in the heads of Departments who remained in their positions, and it must be regarded as a very direct compliment to these officials, upon whom the work of administration devolved. The gas industry shared this confidence, and welcomed the introduction of the Gas Regulation Act. The evils of short-sighted legislation as far as the electrical industry was concerned were, or would be, recognized by the Board of Electricity Commissioners which was now in existence and in operation. There was no such body unifying the gas industry, and they therefore had to look—and he believed they could look with confidence—to the Department of the Board of Trade dealing with gas matters to exercise as far as possible a general guidance and control over gas affairs which would direct and strengthen the industry. The relations of the industry with the Ministry of Transport were possibly not so intimate, but they were of very real importance. As users of raw material in very large quantities, they were greatly interested in questions relating to rates. How far the Ministry to-day could exercise control in this direction, he was not quite sure, but both as road users and as road occupiers, and further as being interested in road construction, they had a very close association, and a very real concern, in the work of the Ministry of Transport. Now, on that occasion, and in that company, there was no need for him to dwell upon the importance of the gas industry. It was fully realized and appreciated in that room, but there were circles in which it was possibly not appreciated to the extent it should be—he referred to Government circles. There the salvation of the country apparently lay not in the development of the gas industry, but in the development of the electrical industry. This was by no means a completely accurate view to take of the position, and the gas industry was dependent on the permanent officials to whom he had referred for the presentation of the case which the industry itself had no *locus standi* to present. He asked them to rise and drink to the toast, with which he coupled the names of Mr. Honey and Sir Henry Maybury.

THE CASE OF THE SMALL GAS UNDERTAKINGS.

Mr. H. C. HONEY thanked all present for the very cordial way in which they had received the toast. He was a great believer in many ways in the old tradition of the anonymity of public servants, but he found it difficult, of course, in a gathering like this, to pretend that it was possible for him to remain anonymous. Indeed, he felt that he was almost at home ["Hear, hear"] in such a gathering as this. A certain magnanimity had been displayed in inviting him there, but might he say that this magnanimity was a little qualified so far as he was concerned by the feeling that they were "getting a bit of their own back." Generally when he had had the pleasure of meeting them in their individual capacities he had had to sit and listen to them. Now they had an opportunity of seeing what sort of a figure he would cut, if they were in the chair and he was the witness appearing before them. [Laughter.] Well, the work that he had had to do during the last few years had brought him in contact with a great many people connected with the gas industry. A number of them he saw sitting before him, and he hoped he might say that in the course of his duties he had made many friends among the members of the gas industry. ["Hear, hear."] For this reason, he was pleased to be with them that day. It was not only the leaders of the industry that he had been privileged to meet. He had come across many men who might not be members of their Institution—men in humbler capacities, connected with the small and very small gas undertakings, and for them, as for the leaders of the industry, he had formed a very sincere and deep admiration. He had been struck again and again, when he had realized the difficulties that some of these men were up against, with their devotion and zeal, and the adaptability with which they had met these difficulties. Now, one of the problems, he thought, that the leaders of the industry would have to face was, What was to be done with regard to the small and very small undertakings? This, it seemed to him, was an important problem—how they were going to combine technical efficiency with commercial success, in the case of undertakings of the kind to which he had referred.

GAS REGULATION ACT STATISTICS.

Probably those present would be interested to know that, under the Gas Regulation Act, powers had been given to something like 415 companies to work on the therm system, and to 134 local authorities—making altogether 549 undertakings which were

working, or were about to work, under that system. Of the remaining undertakings, there were 65 companies who had not obtained powers to charge by the therm, and there were 167 local authorities. But although there were 65 companies who were not working under the therm system, these only represented 3 p.ct. of the total amount of gas sold by companies—97 p.ct. of the gas sold by companies was sold under the therm system, and in the case of local authorities something like 52 p.ct. was being sold under this system. The outstanding companies and local authorities were mostly very small, and they presented a very real and most difficult problem. The fact that the problem was in comparatively small compass, and only referred to 3 p.ct. of the gas sold, did not prevent it being a question that somebody would have to tackle. He did hope that the industry generally would consider very seriously the position of these small undertakings in regard to modern requirements—the requirements which were implied by the therm system of charge as regarded efficiency of supply. Perhaps, if he were not wearying them with too many figures, he might point out that since the passing of the Act in 1920, 124 undertakings—92 of them being companies and 32 local authorities—had applied to the Board of Trade for Orders under section 10. He was referring to these sections in this familiar way, because he was sure that nearly all of those present were acquainted with what he was speaking about. Well, 124 Orders had been made by the Board of Trade under section 10, and if they considered what would have been involved in the way of expense, in the way of delay and trouble, had the industry been obliged to go to Parliament for all these Orders—600 or 700 in number—he thought they would agree that the operation of the Gas Regulation Act, at any rate in this respect, had been a benefit to the industry. He was not there to apologize for the Gas Regulation Act in any respect. He did not say that it was perfect. Very few things were perfect, and he supposed even the Institution of Gas Engineers did not lay claim to absolute perfection. [Laughter.] But taking the long view—and they had to take a long view in these matters—it seemed to him that there had been no measure which could be so truly described as "the charter of the gas industry" as the Gas Regulation Act. He could remember, and Dr. Carpenter would remember, how Sir George Livesey used to talk about the Act of 1868, with its provision with regard to testing burners, as the charter of the gas industry. But they had a much greater charter here—a charter which, as the years went by, would prove to be a real door opening out to greater progress and greater efficiency. Personally, he never thought that they would see very much result from the technical part of the Gas Regulation Act for the first ten or fifteen years. He always believed they would have during the early period a good deal of criticism and a good deal of difficulty, but things were going even better than he had anticipated, and certainly a good deal better than many other people had anticipated. ["Hear, hear."] He thought that now—he hoped he was not wrong, and that they would agree with him—there were signs in the industry of a new spirit of inquiry, a new spirit of research, and a new feeling for efficiency and service which, if not entirely due to the Gas Regulation Act, had been very largely stimulated by it. This kind of feeling, this kind of spirit, he believed, was going to increase; and in the next ten or fifteen years they would see that the gas industry had made great strides in the way of technical efficiency and development. Those of them who had anything to do with the earlier stages of this work might therefore claim to be, as Sir Henry Maybury might claim to be, the makers of a great road.

Sir Henry P. Maybury said he felt greatly honoured at having his name coupled with the toast. While it was quite true that, as Director-General of the Roads Department, his Department had not the same close connection with the gas industry as that of his friend Mr. Honey, still they were very often fairly close together. In fact, he was almost saying that they were an absolute necessity to each other, because if it were not for the operations of those present he might find himself forced to apply for the dole through having joined the ranks of the unemployed. He knew, as Mr. Honey knew, the great value to the community of the industry which their Institution represented, and he felt that any undue interference, or any unnecessary cost put upon the industry, was waste, and was inevitably passed on to the consumer. Serving the public, as they all were, it was their duty, and it was the pleasure of his Department, to try to "make the rough places smooth and the crooked places straight." He need not apologize for being present at a luncheon of the Institution of Gas Engineers, because for more years than he cared to remember he had been a member of the Institution, and he had been made an honorary member during the Presidency of their dear friend Edward Allen. He valued very much indeed his connection with the Institution, which afforded him many pleasant recollections. In a small way at one time he was, like themselves, responsible for the manufacture and distribution of gas. It was a matter of regret to him that the Minister of Transport could not be there that afternoon, because he would have responded to the toast in a far abler manner. On the other hand, he had been very glad of the opportunity of meeting again so many old friends.

Mr. Charles F. Botley, proposing "The Visitors," referred with gratification to the large number of distinguished guests present. Particularly they all appreciated the presence of the President of the Institution of Civil Engineers. They were very pleased also to have with them the Mayor of Preston, who had kindly addressed them that morning. There were many other distinguished gentlemen to whom he would like to refer, did time permit, but one he must mention, because he was associated with a very important undertaking in the country, whose Engineer was to be their next President. He alluded to Mr. W. Woolley, the Chairman of the Derby Gas Company, whose name he coupled with the toast.

An Invitation to Derby.

Mr. W. Woolley said he regarded it as a very great honour to be called upon to say a few words in response to this toast, especially when he looked at the list of distinguished visitors present. On their behalf and on his own behalf he wished to express gratitude for the great hospitality and kindness that had been shown them, and the earnest hope that the meetings of the Institution would add to the prosperity of an already prosperous industry. He understood that the Derby Gas Company's respected and capable Engineer, Mr. J. Ferguson Bell, was to be their next President, and when this came about he hoped the members would pay a visit to Derby. It would be a pleasure then to show them, not only the gas-works, but other local industries which were well worth attention.

Science and Industry.

Mr. James Paterson, submitting "Science and Industry," remarked that the coupling of science and industry was a thing which everyone in this generation should endorse. On looking into the matter, he had come to the conclusion that the linking together of the two was of very recent growth. Industry, as they understood it to-day throughout the length and breadth of the land, was a thing of only some few score years of existence. A hundred years ago industry as they saw it now hardly existed, and in the same way science, which he believed could be described as "systematized knowledge," also a hundred years or less ago was hardly existent. But now industry had found that, by calling science to its aid, progress upwards, and ever upwards, could be made. If industry had not sought the aid of science, industry would not be the root of so much material, and social, and spiritual benefit as it was at the present time. Their own industry had not been backward in seeking the aid of science. Here, again, that co-operation was of very recent growth, and he ventured to assert that science to-day had only touched the fringe of the help it could afford to the gas industry—it was going to assist the gas industry to advance much further. Now, in calling in the aid of science, they had been singularly fortunate in the men who had stood for science, and he would couple with the toast a name which was a household word throughout the whole of the gas industry, a name which carried with it affection—that of Prof. Arthur Smithells.

Prof. Arthur Smithells, in response, acknowledged the progress that had been made within his own lifetime in the approximation of science to industry, and in the promotion of a better understanding between these two realms of action, and nowhere, he ventured to say, had this been more evident than in the gas industry. He also expressed the gratitude which he, in common with all representatives of science who were interested in this industry, felt at the appreciation which was so increasingly shown of the service which science was able to render it. He thanked Mr. Paterson for his kindly reference to himself. It was true that he had tried to direct the forces of science towards the solution of some of the industry's problems, not only because he believed that in this way their industrial success would be increased, but because he believed that every human calling ought to be imbued as far as possible with a proper understanding of the Laws of Nature which applied to it. In severing his connection with the University of Leeds, he had left behind him, in his old friend Cobb, a man who would stand by them quite as faithfully as he had done, and was able to render far greater services than had ever been in his own power to give them. It was a source of singular happiness to him (the speaker) that he still had some connection with the University, through their kindness, in his capacity as Chairman of a Committee which had rendered them some service in the past, and he hoped would render them still greater service in the future.

Mr. J. Ferguson Bell said that the toast of "Kindred Associations" required few words from him to commend it. Their aims and objects were similar to those of their own Society—to improve the practice and enlarge the conceptions of the principles on which their respective callings were founded. The continued advancement which had signalized the engineering, mechanical, chemical, electrical, and gas industries was due in no small degree to the assistance afforded by kindred institutions, by means of which progress was freely communicated to the various members. There was, happily, unity between the various Institutions, whose object was the advancement and prosperity of their respective industries. This, he thought, was strikingly evidenced by the fact that the Institution of Electrical Engineers had again this year, as they had done in 1922, granted the hospitality of their building for the meeting of the Institution of Gas Engineers. The President of the Institution of Electrical Engineers was unfortunately unable to be with them, but they were honoured by the presence of Sir Charles Morgan (the President of the Institution of Civil Engineers, not only the oldest engineering Institution in this country, but one which had from the first embraced within its ranks all branches of the profession), Dr. Charles Carpenter (Past President of the Society of Chemical Industry, and President of the Gas Companies' Protection Association), Mr. W. H. Patchell

(President of the Institution of Mechanical Engineers), and Mr. J. Wilfrid Drake (Chairman of the Society of British Gas Industries). He coupled with the toast the names of Sir Charles Morgan and Dr. Charles Carpenter.

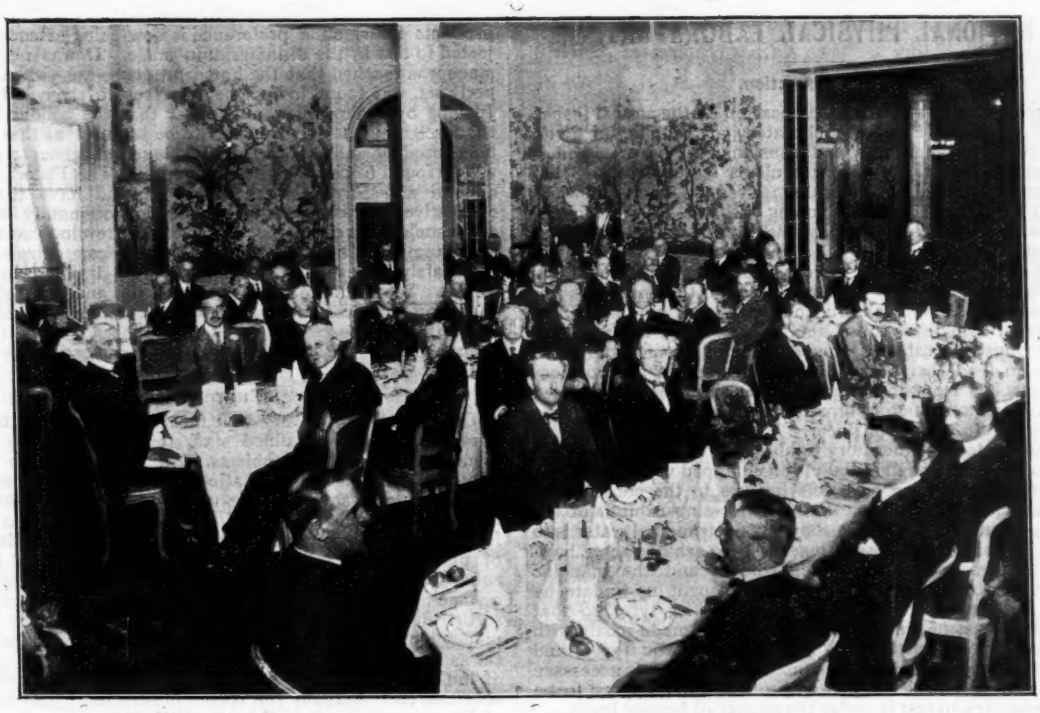
Sir CHARLES L. MORGAN, responding, said everyone must specialize in these days, and so specialized Institutions were necessary. If they were to attempt as one Institution to-day to deal with every branch of the profession, it would be impossible, in his judgment, for the advancement to be made which they saw around them. He himself had been interested in gas for some time. In fact, he operated three gas-works at one period, but they had all disappeared. He was, however, still interested as a Director in one Company. He did not profess to be on the technical side, but he was very much impressed with the advances that had been made in the gas industry within the last few years. The gas engineer of to day had to be a good all-round man, and he had also to be a specialist. It was not sufficient to excel in carbonizing, but he must be a civil engineer, an electrical engineer, and something of a chemist. He must have a really special knowledge of almost every branch of the profession. He was happy to see, as President of the Institution of Civil Engineers, that so many gas engineers were members of the parent Institution.

THE PRESIDENCY.

Dr. CHARLES CARPENTER, after thanking them for the cordiality of their reception, said there were one or two points which he thought as gas engineers they should give their attention to. First of all, with reference to the Institution itself, the circumstances of the war were peculiar, but he did hope they would never depart from the principle of electing the most important of their members to occupy the honourable position of the Presidency for each particular year. It would be a bad day for the Institution if it found itself unable to draw in the future, as it had in the past, upon men famous for statesmanship as Livesey was, for diplomacy as Corbet Woodall was, for sound engineering as Foulis was, for culture as King was, and for mechanical engineering as West was; and he could not believe that an Institution which had in the past produced men of that high standing was likely to be unable to do so in the future. Indeed, he would go a little further, and say that if they did want an ornament or a figurehead, he saw no reason why, out of their own ranks, they could not produce a Beau Brummell. Now, the advantage they had in electing year after year one of their number to the Presidency was that it gave them an opportunity of understanding that member, his aims and his possibilities, to a greater extent and degree than they otherwise could. Occupying that position, he gave them a chance of testing his worth as a broadminded man, as one with broad ideas and a wide belief in the possibilities of the industry in the future. But he would suggest that it would be unfortunate if they looked upon the occupancy of the Presidential Chair as the attainment of the highest goal in the profession of gas engineering. Too often, he thought, it was the case. He suggested that it should be looked upon as an intermediate stage. Some of the important members of the gas profession were absent that day—particularly he might recall two of his old friends, at whose feet, curiously enough, he sat alternate weeks throughout the year, and who, at a cardinal and important stage of their lives, quitted direct association with management of gas undertakings (in one case company, and in the other corporation), to occupy a more important position in the administration of gas affairs.

ADMINISTRATION THE HIGHEST GOAL.

He suggested that it was with the members of the Institution that the future administration of gas affairs should lie. He could not say that they had the baton of a Field Marshal in their knapsacks, but he could use that simile, and suggest that in their portfolios or attaché cases—he believed that was the proper expression nowadays—there was that little ivory or boxwood or ebony hammer associated with the chairmanship of a gas undertaking. He suggested that this was their right in the future; that their reward for the knowledge which they had acquired with so much expenditure of energy and thought, and with such sacrifice of time, should be in the administration of gas undertakings from the highest point of view. He could not believe that the gas engineer was less endowed with commonsense or administrative capacity, or less tactful in dealing with men, than was the average person that they found at the head of a gas company, and he would bring to bear upon his work a specialized knowledge which could not be acquired by outsiders. He did feel—and he spoke with some experience—that in too many cases the career of the gas engineer reached an end when he had become the technical chief of his undertaking; and the object of his remarks was to suggest that this should be regarded by them all as an intermediate stage. They would, of course, have to acquire the necessary interest, to get their feet on the bottom rung of the ladder, but this was quite easy. It was only a question of taking up some shareholding in different undertakings. This was certainly the secret of the success of the two gentlemen to whom he had already referred—Mr. H. E. Jones on the one hand, and Mr. Charles Hunt on the other—and he suggested that others should do the same. He was quite certain that the future would see far more—as it should see far more—of those associated with the industry in important positions as administrators of its affairs. In the case of his own Company, the majority of the members of the Board had been trained in gas-works. ["Hear, hear."] He did not, of course, want a Board composed wholly of gas-trained men. He realized it was important to have a leaven of outside influence which could be useful in a great many ways. He did suggest, however, that gas should not continue to be an exception to the rule, but that it should be much more manned and worked administratively by those who had begun at the bottom and had risen to that position.



[*Photo. by Kamra Press Studios, Ltd.*

A PART VIEW AT THE PRESIDENT'S LUNCHEON.

THE INSTITUTION.

Sir ARTHUR DUCKHAM said he rose with great trepidation, for it was the first time he had ever spoken in public with his late Chief present. He started, fortunately for himself, under Dr. Carpenter, and fortunately he caught from that gentleman what he might perhaps term the "bug of work." He got to know that

his job had not only to be well done, but rather better than well done. He had to propose "The Institution of Gas Engineers," and, in doing so, he would remark that what Dr. Carpenter had just said to them constituted one of the most helpful speeches to which they could have listened. To many it had given a line of further advancement and further purpose in life, and the great point of importance was the source from which it had come. If they were asked to say who was the gas engineer *par excellence* to-day, they would say Dr. Carpenter, because he had had that training right through which they all, as gas engineers, would like to enjoy. With regard to the Institution, he thought it must be a very proud time for both the President and the members. If they looked back to the old days, and thought what the Institution did, they saw how narrow, in a way, was its outlook, how it was interested in the form of a particular carbonizing plant, or gasholder, or some other piece of apparatus. Now they had an Institution helpful in every branch. The reports of Committees, &c., were of absolutely incalculable benefit to the gas industry throughout the country. The manager of a small works could not hope to solve all his own difficulties. He had not the training, the assistants, or the money to expend; and when they realized what help the Institution had been to such men, they would agree that it was absolutely essential to the gas industry. He had noticed lately that the industry was rather out to sell gas, and the President in his address that morning had said that the function of the Institution was to promote the advancement of the gas industry in all or any of its branches, and for the benefit of mankind. Personally he looked upon the gas industry in a rather different way. He would say that the gas industry was primarily for the benefit of mankind. They, as an industry, incidentally sold gas, but their first duty was that of service. It was the feeling of all gas engineers that their task was to show how this could be done by gas. Mr. Tagg had undoubtedly been a most successful President. He (the speaker) hoped that the position would prove to be only an intermediate stage, and that he would be before long either President or Chairman of a gas undertaking—in which capacity he would certainly be successful. If they wanted tact, commercial skill, or technical knowledge, Mr. Tagg had it.

The CHAIRMAN, in response, said the Institution had achieved much for the industry, and was capable of doing more. There was a wonderful sense of unity and co-operation, not only between members of the Council, but among individual members, which led them to contribute all that lay in their power towards increasing the usefulness of its work. The position of President made considerable calls upon one's time, and he would in this connection like to acknowledge the generous and loyal assistance which his colleagues at Preston, Mr. Newbound and Mr. Heald, had given him, without which it would have been impossible for him to devote the time to the work which the Institution had claimed.

Mr. JOHN WILKINSON, on behalf of the members of the Council, who were the personal guests of the President, tendered their sincere thanks for the hospitality extended to them, and on behalf of the members generally thanked both Mrs. Tagg and the President for inviting them to the reception that evening.

NATIONAL PHYSICAL LABORATORY.

Annual Inspection.

The reception of visitors on the occasion of the annual inspection of the National Physical Laboratory at Teddington by the General Board assumes greater dimensions year by year, and on the afternoon of Tuesday, the 24th ult., a larger company than ever before assembled to see for themselves the manner in which this great national institution is coping with the calls of science and industry for the aid of the physicist in fundamental problems and investigations.

Few, if any, of the critical visitors can have been aught but gratified with the results of their inspection of the apparatus and experiments which were shown and explained by the staff of specialists attached to the Laboratory. While many of the recondite physical problems of gas manufacture and supply do not seem to lend themselves to investigation in a laboratory wholly detached from their industrial environment, much was seen at Teddington which is directly or indirectly of great interest and service to the gas engineer.

The road materials laboratory established under the Engineering Department has been initially well equipped with appliances for preparing and testing materials for use in the construction and re-surfacing of roadways. Some interesting exhibits of the wear of road surfaces by traffic show how detrimental water is to the durability of bituminous coatings. These exhibits refer, however, to tests made with iron-tyred wheels, and the machine which is used for these tests should be brought up-to-date by provision being made for changing the wheels or tyres, so that the durability test of the road surface may be made partly with solid-rubber tyres, partly with smooth pneumatic types, and partly with ribbed or studded, pneumatic tyres. If it is necessary to test the surface at all under iron tyres, it would appear to be equally necessary to test it under the impact of horses' hoofs.

TAR *versus* ASPHALTIC BITUMEN.

The circular track in which the road surface is laid for testing should be susceptible of use in another direction—viz., for investigation of the degree of contamination of road washings by the detritus of bituminous road materials. The customary test of a material appears to comprise a period of running the wheels on the prepared track while dry, followed by a period during which the track is kept wet. It has been shown conclusively by the road trials made at Alresford for the Joint Committee of the Ministry of Transport and the Ministry of Agriculture and Fisheries that a tarred road surface, so long as it is in good condition, gives washings which are perfectly harmless to fish-life and pond vegetation, but that, when disintegration sets in through wear and tear of the surface, the washings may become harmful through the colloidal silt which they carry. Very few of the roads surfaced with bitumen other than tar have yet been in use long enough to have reached the disintegration stage, and there has been little opportunity of observing whether a similar harmful silt is not the ultimate product also of the breaking up of these bituminous surfaces. The Teddington trial track, however, would allow the disintegration stage to be quickly reached, and washings could be collected from it for investigation of their effect on fish-life and pond vegetation. The area of the running track is of course very small in comparison with the roadway on which tar was tested to the disintegration stage at Alresford, but the size of the "pond" and the flow of water could be correspondingly reduced in order to subject the fish, &c., to a similar concentration of washings. Perhaps the Federation of British Industries will take up this question with a view to seeing that the foreign products to which a preference is now being extended are subjected to test in the disintegration stage. It was not until this stage was reached that the home product—tar—when once properly set, was found to become injurious to river and pond life. Judging by analogy, it would appear that the colloidal silt from the foreign material is as likely to be harmful as that from the home product, and that the favourable reports given to the former will be found to be altogether premature. The Federation should appoint a research Committee *ad hoc* and have the question exhaustively investigated. The angling community should welcome such an investigation, which would show in what conditions any bituminous material, whether derived from petroleum or tar, may safely be used for surfacing roads draining into fishing waters. While there is probably little analogy between the causation of cancer and the inception of irritant disease in fish, it is worth while bearing in mind that cancer, similar to sweep's cancer, is more prevalent among workers in paraffin works than in tar works.

PHOTOMETRY.

The Laboratory is very well furnished, in respect both of apparatus and highly qualified staff, for research work in fundamental photometrical problems. An improved type of flicker photometer for heterochromatic photometry has recently been developed, and should prove useful in estimating the relative intensity of sources of light of which the colour is too divergent for trustworthy comparisons to be made with the ordinary types of photometers. Integrating spheres for measuring the mean spherical candle-power of sources of light have also been brought a stage nearer perfection by recent work at the Laboratory. A further development is the provision of a set of rooms for trials of daylight illumination, as affected by wall coverings, &c., and the same rooms should be useful for comparative tests of methods of indirect artificial lighting in relation to decorative colour schemes, &c. Actually the rooms illustrating "The Seven Ages of Woman" in the Gas Exhibit at Wembley show that the relation between lighting and wall colouration is in no small measure responsible for the soothing charm of those rooms.

METROLOGY AND THERMOMETRY.

It is impossible on this occasion to refer in detail to the exhibits at Teddington of standards and comparators for use in metrology, and of methods of testing barometers, graduating chemical glassware, &c. A good deal of work is in progress on conductivity, in relation to both high-temperature and low-temperature insulation, and the thermometer testing equipment is in constant use for the verification of enormous numbers of thermometers for medical and industrial use as well as for scientific research. The National Physical Laboratory is certainly now well justified by its works, whatever may have been the qualms felt in certain quarters at and shortly after its foundation in the year 1901, and the Director, Sir Joseph Petavel, and his staff are to be heartily congratulated on their achievement.

Recent Wills.—Mr. Arthur F. Phillips, who died on March 31, aged 81, left estate of the value of £132,729, with net personalty £130,754. Dr. Frederick Stroyan, of Aldershot, left £21,947, with net personalty £19,395.

Institution of Public Lighting Engineers and Superintendents.—The Institution of Gas Engineers, at their Council Meeting last week, appointed Mr. J. W. M'Lusky, of Glasgow, and Mr. H. H. Gracie, of Edinburgh, to represent the Institution at the forthcoming annual meeting and conference in Glasgow of the Institution of Public Lighting Engineers and Superintendents.

GENERAL REPORT.

THE Annual General Meeting of the Institution was held on Tuesday, Wednesday, and Thursday of last week, June 24 to 26, at the Institution of Electrical Engineers, Victoria Embankment, London, under the Presidency of Mr. SAMUEL TAGG, M.Inst.C.E., Engineer and Manager of the Preston Gas Company. There was a very large attendance when the President took his seat—among those supporting him being the Mayor of Preston (Alderman F. W. F. Mathew).

The PRESIDENT (who, on rising, was greeted with loud applause) said: Ladies and gentlemen, may I, on behalf of the Council of the Institution, welcome all those present this morning, and express the hope that the meetings will be both pleasurable and profitable?

Confirmation of Minutes.

The PRESIDENT: The first business is a resolution that the minutes of the last annual general meeting and of the intervening special general meeting be taken as read, and confirmed. I beg to move that.

Mr. J. D. SMITH (Belfast): I have much pleasure in seconding the resolution. (Agreed.)

Congratulations.

The PRESIDENT: I have pleasure in announcing that a telegram of congratulation has been received from the Société Technique du Gaz en France, expressing their best wishes for the success of this meeting, and anticipating with pleasure the visit of the members to Paris later in the week. May I take it that it is your wish that an adequate reply should be sent to the French Institution? (Agreed.) I also have to acknowledge the receipt of a similar cablegram of congratulation from the American Gas Association, and a reply in due course will be sent.

The messages were in the following terms:

> Au nom Société Technique réunie congrès centenaire nous vous envoyons nos vœux les plus sincères pour plein succès de votre meeting. Attendons impatiemment l'arrivée des délégués de votre illustre Corporation pour partager avec eux la joie confraternelle de nos fêtes jubilaires.
>
> ROULAND, Président.

> Greetings from American Gas Association. Best wishes for most successful meeting, followed by prosperous year.
>
> ALEXANDER FORWARD, Secretary-Manager.

Appointment of Scrutineers.

The PRESIDENT: It has been suggested that Mr. Herbert Lees, of Hexham, and Mr. Lawrie Trewby, of Mill Hill, be appointed Scrutineers for the examination of the balloting lists. Is that your pleasure? (Agreed.)

The Institution's Gold Medal.

The PRESIDENT: My next duty is a pleasurable one, and it is a privilege which I am sure my predecessor in office would have liked to exercise. It is to ask your acceptance, Mr. Stephen Lacey, of the Institution's gold medal, which has been awarded to you by the Council for the paper read by you at the Belfast meeting last year on the "Flow of Gas in Pipes." This medal is reserved for papers of distinction, among which yours takes very high rank; and the members of the Institution will agree that you have added to the service which you then rendered by a recent interpretation of your researches which will widely increase their availability. I have very much pleasure in asking you to accept the medal. (Applause.)

Mr. STEPHEN LACEY: I need hardly say that I very much appreciate the great honour that has been done me in presenting me with this medal. I thank you, Sir, for the very kind remarks you have made, and I thank all present for the cordial way in which they have received me.

The medal was inscribed:

> Institution of Gas Engineers. To Stephen Lacey, B.Sc., Assoc.M.Inst.C.E., for paper on "Flow of Gas in Pipes"; read June, 1923.

The Diplomas.

The PRESIDENT: The next item is an innovation in the programme, and it is the presentation of the diplomas which have been secured under the Education Scheme of the Institution. I have to call upon Mr. P. C. Gardiner, and Mr. J. Hood to whom have been awarded the diploma of the Institution of Gas Engineers. Mr. Gardiner, I have very much pleasure in handing you this first diploma issued under the scheme, and I congratulate you upon the success you attained and the very excellent thesis which you contributed to secure it. Mr. Hood, you share in the distinction of being one of the first recipients of the diploma, and I congratulate you also on your success.

The Presidential Address.

The PRESIDENT, who, on rising, was again cordially greeted, then delivered his address, which will be found on p. 87.

Vote of Thanks to the President.

Mr. JAMES PATERSON: Mr. President, I crave your permission to bring a motion before this meeting. Ladies and gentlemen, I have the very great pleasure, and I esteem it a very great privilege, to move a hearty and cordial vote of thanks to the President for his stirring and enthusiastic address. I am tempted to be briefly reminiscent, for we are carried back by the President to early days, when he says that his association with the industry dates from birth. I am tempted to recall an incident that occurred, shall I say, in the course of last century, when I, as a novitiate in the industry, was taken metaphorically by the hand by our President. I was then a junior official in the industry; and it was my enormous privilege, and an advantage that has always been with me, that my first lesson on a gas-works was given to me by Mr. Tagg. (Applause.) I am sure that those who have not had this privilege of an early introduction to gas at our President's hands will agree with me that, throughout his professional life he has always been both ready and eager to hold out a helping hand to all who have sought his assistance. I think that to-day he has brought to a culmination his many services to the industry in the address that he has given us. Mr. Tagg, I am sure, has been aware for some time that the address he was to deliver to the Institution at this meeting has been eagerly anticipated; and I am confident that I shall have the approval of everyone at this large and representative gathering when I say that the expectations have been fully realized. The President has made mention of the fact that we have really reached to-day the twenty-first anniversary of the union of the two representative gas bodies. We are to-day such a united, complete, and homogeneous organization, that many of us perhaps have forgotten that there were at one time two bodies. The President has taken the opportunity to review the events of the industry during that period, and he has not only shown the progress that has been made, but holds out further hopes for the future. He has crystallized for us the activities of the industry throughout the whole of its branches, and the point which particularly appeals to me, and I feel sure to many in this room, is that he has shown how by the Education Scheme the young men of the industry may be prepared for the high positions they are destined to fill. In these days there is no doubt that education in the highest and broadest sense of the word is what we want in the gas industry. We must never be, and have never been, satisfied with things as they are, but must aspire continually to what is better. Thus we shall achieve that higher position and that higher service to the community which the gas industry is surely destined to reach. We must not discuss the address; it is neither necessary nor desirable, but when we record our

thanks to Mr. Tagg for it we do so sincerely. While congratulating him upon the address, we can congratulate ourselves that we have had such a leader for our Institution during the past year. As one who has sat at his side through meetings in Council and Committee, I have been much impressed. I think the work he has done shows that the President has given whole-hearted care and unremitting attention to the affairs of the Institution.

Mr. H. D. Madden (Cardiff): We have listened to a very fine Presidential Address, and one of a high order, which I think is a profession of faith in the industry as it stands to-day. I have not had the advantage of knowing the President, as my colleague Mr. Paterson has, for very many years; but I can say that for five years I have had his friendship on the Council of the Institution. We have all looked forward to this day, and anticipated an address of great excellence, and we have got it. It gives me very much pleasure to second the vote of thanks so ably proposed by Mr. Paterson.

The Mayor of Preston.

Alderman Mathew, who was greeted with applause, said: It is my pleasure and my privilege to be here to-day to support what both the mover and the seconder have said touching the address just delivered by the President. It is my pleasure, because your President is a personal friend of mine; and it is my privilege, because, as Chief Magistrate of the Borough of Preston, I am here to represent the town, to show its appreciation of Mr. Tagg as a townsman. At the end of his term of office, it is a very remarkable thing for a President to be able to give such an address, and he can also pride himself on the fact that, at the close of his year of office, he has been able to gather round him such a body of men as are here to-day, representative of the gas industry throughout the country. One point that occurs to me as a commercial man, and which I should like to refer to, is the incentive that has been given to the gas industry by the rise of the electric light. Electricity has given the gas industry a stimulus to see what could be done, and what improvements could be effected. Casting my memory back, I can recall the time when gas in a small country town was anything but pleasant. It was very sparingly used, as it was rather costly, and the juveniles had to use candles or tallow dips to light them to bed, because of the economy of them. In my day I can remember distinctly the old sulphur matches, with the extinguisher and the snuffers. There have been very large strides made since those days. Although electric lighting has come to the front, you and your Institution have made even larger strides. Instead of, at the first difficulty that arises, feeling you have no case, you have, by research and by hard work, proved that there is so much value in gas undertakings that many of us would like very much to have some of the original shares in them. (Laughter.) There is another matter that appeals to me, and that is your Education Scheme—what I should call a vocational education. I understand that the two diplomas which have been given to-day are the first. There will be many more, because in the years to come one of the very first questions that will be put to applicants for positions of worth will be, "What diplomas do you possess?" The scheme will raise the standard of the younger members who are making preparation for the years to come, when they will take the places of many who are sitting before me to-day, and who will not only be waiting to take their places, but will be capable of taking on the work that will be expected of them. I said it was my privilege to be here to-day as representing Preston. Mr. Tagg, from the very moment he came into our town, took an interest in everything that was for the well-being of Preston. He was one of the first to move in the formation of the Chamber of Commerce, and if I remember rightly was the first Hon. Secretary; and to-day in Lancashire the Preston Chamber of Commerce is the third largest in existence. It comes after Manchester and Liverpool. This shows you how well the foundation of the Chamber was laid, and a great deal of that is due to your President. There is another matter quite as important as Chambers of Commerce, and that is golf—in its proper place. (Laughter.) Now I may tell you that in golf your President excels. Only last year he was the Captain of the Fulwood Club, and as Captain he displayed his business ability by improving many of the things that needed improvement in the Club. I am given to understand that his year of office and his place on the Executive will make a lasting impression on the course. In conclusion, I should just like to sum up what we in Preston think of Mr. Tagg. He is sincere, he is thorough, and he is dignified. Whatever he undertakes he uplifts, and we appreciate him as a townsman.

The vote was carried with acclamation.

The President: I am exceedingly obliged for all the kind things that have fallen from the speakers, and for the sympathetic reception you have accorded them. I particularly appreciate the presence of the Mayor to-day. It is a personal compliment which I did not anticipate, and it has given me very great pleasure to see him. I am also obliged for the courteous hearing which my rather long address received. Thank you very much.

Annual Report and Accounts.

[See "Journal" for June 11, p. 738.]

The President: The annual report of the Council and the accompanying statement of accounts have been circulated, and I beg to move that they be taken as read and adopted.

Mr. W. J. Smith (Bolton): I beg to second that.

The President: If nobody desires to make any comments, I will put the resolution to the meeting.

The report and accounts were then adopted without discussion.

The Committee on Education.

The President: I have now pleasure in calling upon Mr. F. W. Goodenough, the Chairman of the Advisory Committee on Education, to submit the report of that Committee.

Mr. F. W. Goodenough then presented the following report:

Report of the Advisory Committee for the year 1923-24.

[The Advisory Committee on Education consists of:—Mr. F. W. Goodenough (Chairman), Messrs. Samuel Glover, Thomas Goulden, Walter Hole (Organizing Secretary), and Samuel Tagg, representing the Institution; J. Bridge and S. B. Chandler, representing the Junior Gas Associations; A. Abbott, C. H. Creasey, W. Gannon (co-opted), Drs. A. Morley and A. Jamieson Walker, representing the Board of Education; Mr. J. T. Ewen, representing the Scottish Education Department, and Prof. Thomas Gray, representing the North British Association of Gas Managers.

The following form the Board of Examiners:—*Gas Engineering*—Messrs. H. D. Madden (Cardiff), Chairman of the Board; W. J. Smith (Bolton), and J. S. Thorman (London). *Gas Supply*—Messrs. S. B. Chandler and S. Lacey (London) and J. Wesley Whimster (Bath).

The Consultative Committee is composed of the Advisory Committee and Mr. W. Calderwood (Association of Technical Institutions), Major T. Worswick (Association of Principals of Technical Institutions), Mr. Harold Hunter (Association of Teachers in Technical Institutions), Prof. John W. Cobb, and Mr. F. S. Sinnatt.]

In connection with the Education Scheme, the past year has been largely one of foundation laying. It is hoped that these foundations have been laid broad and deep, and have been such as will worthily bear the edifice which we trust the passing years will see raised thereon. There are three characteristics of foundation work everywhere:—

1. It requires a great deal of spade work.
2. The results, as far as they can be seen at the time, and judged by themselves, appear altogether incommensurate with the expenditure of time and work which has been put into them.
3. Notwithstanding all this, they are absolutely indispensable. No building can stand which has not adequate foundations on which to rest.

Part of this foundation work has consisted in first of all inducing the local Technical Institutes to interest themselves in the Scheme. Here we seemed in many districts

to be travelling in a vicious circle. On the one hand, young men who would make capital students are, perhaps naturally, rather diffident about inquiring for classes which are not advertised. On the other side, financial arrangements loom large in the minds of local authorities when considering any proposed additional classes. In turn, therefore, they wish to be assured of a sufficient number of students to justify them in incurring the expense involved. They have frequently referred to the lack of demand for such classes, or even of inquiry as to their existence; and that has been held to warrant them in deferring any adoption of the scheme until an adequate number of students could be guaranteed. The gas industry is in a particularly difficult position in this respect, inasmuch as there is usually only one gas undertaking in each town, and the number of students must, therefore, of necessity be small.

It is hoped to overcome this difficulty very largely by making particular towns, where the facilities are adequate, centres, to which students from other undertakings within a reasonable radius might come. A number of undertakings within (say) a 20-mile radius might provide a sufficiency of students, where an individual undertaking would fail. This, however, brings us up against another set of financial difficulties. If such centres are to be made possible, the undertakings must be prepared to grant facilities and financial assistance to suitable students. It is almost impossible to expect young men, at the outset of their career, when earnings are small and other expenses are high, to face the cost of a double railway journey, three times each week, throughout the 30 odd weeks of an ordinary winter session's class work, which the Scheme involves, coupled with the outlay in class fees, books, and instruments, unless they receive assistance in some way.

That assistance may take one or other of the following forms:—

1. The payment of travelling expenses to selected students.
2. The re-imbursement of students in respect of class fees.
3. The grant of increase of salary or wages to successful students.

Facilities are also necessary for daytime study, in order that a suitable curriculum may be covered without undue strain on the student. It is hoped, therefore, that undertakings will be willing to release suitable students for at least one half-day in each week. In this way it would be possible to take both afternoon and evening lectures on one day out of the three.

Another side of this necessary foundation work has consisted in the interesting of the junior members of the staffs of the undertakings of the country in the Scheme itself. This has been attempted by a series of fruitful conferences of the Junior Gas Associations throughout England and Scotland, at which the Scheme has been expounded by the Organizing Secretary. One difficulty has been met in this direction this year, which will not recur. The Advisory Committee has necessarily been obliged to make arrangements for the recognition of previous work of students to take the examinations for the Higher and Diploma Certificates. For the purpose of passing to the higher stages, the Committee decided to recognize—for a short period of years—the certificates granted by the City and Guilds of London Institute up to 1924. The latter, however, are granted on a single subject examination. The result has been that a large number of students have preferred to endeavour to secure a certificate which, though easier to obtain, will be of decreasing value as the Institution's own Scheme gets more fully into operation, rather than face the greater amount of work involved in taking an examination under the Scheme of the Institution.

The third important side of the foundation laying has been the consideration, and in many cases, the amendment, of courses of study prepared by technical institutes in accordance with the Education Scheme adopted by the Institution. Needless to say, these have needed very careful attention in order to secure a suitable and fairly uniform series of courses, while at the same time making a full allowance for variable local circumstances. In this, as well as in other directions, the Committee have been largely guided by the expert knowledge of the representatives of the Education Departments, and wish to place on record their appreciation of the splendid services rendered to the Industry and the cause of Education by those members.

Although Group Course students will be presented for examination this year (1924) only in the following centres:

Bradford Technical College,
Halifax Technical College,
Huddersfield Technical College,
Manchester College of Technology,

the Course work under the Scheme has been commenced at

Barnsley Technical School,
Bath Technical College,
Bournemouth Technical College,
Dewsbury Technical School,
Plymouth Technical School,
Regent Street Polytechnic, London,
Salford Technical College.

Dr. Edgar, of the Regent Street Polytechnic, writes that, although he has no students to present this year, he hopes to have a good entry next year. This is probably true of many other places as well.

For students who have been compelled to avail themselves of the facilities of Section II. of the Scheme (external students), examinations have been arranged at the following Institutes:

Chester School. School of Science and Art.
Cork Technical College.
Glasgow, Royal Technical College.
Huddersfield Technical College.
Inverness, County Education Offices.
Lincoln Technical School.
Newport (Mon.) Technical College.
Oswaldtwistle Technical School.
Preston. Harris Institute.
Shrewsbury Technical School.
Westminster Technical Institute.
Workington Technical School.

The total number of candidates examined in May, 1924, was 60, of whom 36 were in Section I. (internal students), and 24 in Section II. (external students). In view of all the circumstances, this number is not considered unsatisfactory for the first year of a new scheme and for a transitional period.

Consideration has also been given, in a series of conferences, to the application of the Scheme to Scottish conditions. Thanks to the good spirit shown by all parties, and the anxiety of everyone to further the true interests of education, difficulties which at one time appeared to be serious have been either successfully met or the points creating them have been waived, pending further experience of the Scheme in actual practice. It is hoped and expected that the Scheme will be in full operation in Scotland next session.

The past year's experience of the Scheme in operation has revealed the need for an extension of its scope in a downward direction. There are many men in the industry who are anxious to improve their technical knowledge, but who, either through lack of suitable educational opportunities or attainments, or other cause, are unable to avail themselves of the Scheme as it stands at present. It is hoped to meet this need by establishing minor group courses of a suitable character, and the Committee are now giving this matter earnest consideration.

Mr. F. W. GOODENOUGH, in submitting the report, said: I am very proud of the honour of presenting to the Institution the first annual report of their Advisory Committee on Education. In doing so, I will endeavour to set the precedent of brevity in speech in inverse proportion to the importance of the subject, and I am assisted in this by the fact that reference has already been made to the Education Scheme by all the previous speakers. I should like to thank the President for the very kindly reference that he has made to myself in his most admirable address, but I really must disclaim the amount of credit that he has given me in regard to the work of the Advisory Committee. For what has been done, thanks are due to the earnestness and enthusiasm of one of the most keen Committees over which I have ever had the privilege of presiding, and not least on that Committee to the very great interest that has been taken in the subject—the very practical interest—by your President. I have had the very greatest assistance from him in all the work that has been carried out. Then we also owe a very great debt, as your President said, to the assiduous, broad-minded, and painstaking co-operation of the representatives of the Board of Education, and not by any means least, the enthusiastic work, and very hard

slogging work, of Mr. Walter Hole, from the commencement. You are also fortunate in the Board of Examiners that the Advisory Committee have persuaded to undertake the by no means easy or thankful work entailed in that office, and you are fortunate in having as Chairman of that Board Mr. Madden, whose interest and enthusiasm in education are of the highest. As you have the report, and, I hope, have read it, or will read it, I need not deal with it at any length. As it says, the principal part of our work has been largely in the nature of foundation-laying, so that there is not much to be seen for a very great deal of labour. As your agenda shows, we are finding it necessary, and shall undoubtedly find it necessary, to make some adjustment in the details of the scheme as we go on, in accordance with our experience; but our aim always has been, and will be, to make the scheme at once attractive and practicable to students, and to raise the standard of quality still higher of those who obtain these certificates and diplomas, so that ultimately, as has been said, the possession of a diploma will be a very definite indication of a man's fitness for high office, either on the works or on the district. As I have said, we have endeavoured to make the scheme attractive and practicable for students. I would endorse the President's appeal, and the appeal in the report, for the giving of facilities by undertakings to students—not least by affording them time off during their working hours, so as not to put upon young men too heavy a load of nightwork, which is not good for them, either from their own personal point of view or their value to their employers. With these very few comments on the report, and with that appeal to you as members and to your Committees for the assistance that is so necessary to make this scheme a success, I submit the report of the Committee, and move its adoption.

Mr. J. PATERSON: I beg to second that.

The motion was carried unanimously.

Revision of the Education Scheme.

The PRESIDENT: There are one or two drafting amendments to be made in the education scheme, to ensure its more successful working, and also to ensure that the original intention shall be given effect to. I have very much pleasure in moving that the alterations as set out by circular be made, coupled with an addition which refers to section 3, so that paragraph 3 (c) will read: "who have passed the higher examination in the subject (Gas Engineering or Gas Supply), for which they desire to obtain the diploma, and have passed the ordinary examinations in the other subject—Gas Supply or Gas Engineering, as the case may be." I think you will realize that all these are merely details which we desire to vary in accordance with our Constitution, so as to bring the scheme really into line with what we find in practice is desirable, and what really was intended at the outset. I therefore have much pleasure in formally moving the adoption of these amendments.

Mr. F. W. GOODENOUGH: I second that.

The motion was carried unanimously.

The following is the circular referred to:

PROPOSED AMENDMENT OF THE "SCHEME FOR THE EDUCATION AND CERTIFICATION OF THOSE ENGAGED IN THE TECHNICAL WORK OF THE GAS INDUSTRY."

SECTION I. (Internal Students.)

That Paragraph 6 (d) *re* qualification for Higher Certificate shall read:

(d) be restricted in Gas Engineering to those engaged on the practical (as distinguished from the clerical) side of gas manufacture, and be restricted in Gas Supply to those engaged on the practical (as distinguished from the clerical) side of gas supply.

SECTION II. (External Students.)

That Paragraph 5 (a) *re* qualification of Candidates for Higher Certificate shall read:

(a) That they have been engaged in the practical (as distinguished from clerical) work of gas manufacture for at least three years previously if desiring to sit for examination in Gas Engineering, and that they have been engaged in the practical (as distinguished from clerical) work of gas supply for at least three years previously if desiring to sit for examination in Gas Supply.

These respective paragraphs now read:

(d) be restricted to those who are engaged in the practical (as distinguished from the clerical) side of Gas Manufacture or Supply.

(a) That they have been engaged in the practical (as distinguished from clerical) work of Gas Manufacture or Supply for at least three years previously.

PROPOSED REVISION OF ARTICLES OF ASSOCIATION 6 AND 7.

That the following be added to Article 6:

"(3) or shall hold the Diploma of the Institution in Gas Engineering or Gas Supply, and shall occupy some responsible position in the engineering department of a Gas Undertaking."

That Article 7 be altered to read:

"7. Subject as aforesaid every candidate for election or transfer into the Class of Associate Member shall be not under 24 years of age (unless he shall hold the Diploma of the Institution in Gas Engineering or Gas Supply), and shall be actually engaged as a manager of a Gas-Works, or shall occupy some other responsible position in the engineering department of a Gas Undertaking."

Articles 6 and 7 now read:

6. Subject as aforesaid every candidate for election or transfer into the Class of Members shall be not under twenty-four years of age, and shall come within one of the following conditions:

He shall have been regularly educated as a Gas Engineer, and either (1) shall have been prominently occupied in the conduct of a Gas Undertaking for at least five years at the time of his election, or (2) he shall be in practice as a Consulting Gas Engineer, and, in the opinion of the Council, have acquired sufficient eminence in the said profession.

7. Subject as aforesaid every candidate for election or transfer into the Class of Associate Members shall be not under 24 years of age, and shall be actually engaged as a manager of a Gas-Works, or shall hold some other responsible position in the engineering department of a Gas Undertaking.

Eleventh Report of Gas Investigation Committee.

The PRESIDENT: The next business is the presentation of the Eleventh Report of the Gas Investigation Committee on "Aeration and Air Injection." I will ask Prof. Cobb to introduce it, and then Mr. Wood will summarize it.

Prof. COBB then introduced the report—see p. 91.

Twelfth Report of Gas Investigation Committee.

The afternoon session on Tuesday opened with consideration of the Twelfth Report of the Gas Investigation Committee, dealing with "Waste-Heat Boilers attached to Continuous Vertical Retorts."

Prof. COBB introduced this. The report and remarks will be found on p. 106.

Methane from Carbon Monoxide.

Next came a communication from the South Metropolitan Gas Company dealing with the subject of "Methane from Carbon Monoxide."

Prof. COBB presented this, and Mr. E. V. EVANS went fully into the communication—see p. 126.

Report on Testing of Gas-Cooker Ovens by the Gas Investigation Committee.

The first day's proceedings were brought to a close with the presentation of another report of the Gas Investigation Committee, this time on the subject of "Standard Methods of Testing Gas-Cookers."

This report (which was presented by Mr. C. F. Botley) appears on p. 130.

The Benevolent Fund.

Wednesday morning's session opened with the Annual General Meeting of the Benevolent Fund (see p. 105).

The PRESIDENT (acting on a suggestion by Mr. Percy S. Hoyte) repeated an appeal which he had made during the meeting for further support, at a convenient point during the subsequent Institution meeting, when there was a crowded attendance. He said: With an Institution a thousand strong, it is doubtless due to want of knowledge of the position that the subscriptions to the fund amount to so

small a sum as £280 a year. This is a most deserving fund, and I do appeal to those of you who are not already subscribers to allow your names to be added to the list.

Regenerative Coal Gasification System at Aylesbury.

Mr. A. G. LANE, of Aylesbury, when the Institution meeting was resumed, presented a paper on "The Regenerative Coal Gasification System at Aylesbury."—see p. 149.

Dr. M. W. TRAVERS, F.R.S., and Mr. F. W. CLARK contributed supplementary statements, and the discussion which ensued lasted until the adjournment for luncheon.

Gas Research Fellowship.

Prof. COBB, after luncheon on Wednesday afternoon, presented the Report of the Institution Gas Research Fellowship, on "The Gasification of Coke in Steam, with special reference to Rates of Gasification and Composition of Gas Produced."

Dr. PEXTON subsequently gave a *précis* of the report.

These, and the discussion which ensued, will be found on p. 162.

Refractory Materials.

Mr. W. EMERY, of Stoke-on-Trent, read a paper on "Silica Gas-Retorts."

Mr. J. P. LEATHER (Hon. Secretary to the Committee) afterwards introduced the report of the Refractory Materials Joint Research Committee.

This paper and report, together with the discussion thereon, will be published as a supplement to the "JOURNAL" next week.

New Coal-Gas Works at Garston.

Mr. R. E. GIBSON, of Liverpool, opened the proceedings at the final sitting, on Thursday morning, by reading a paper on "The Construction of New Coal-Gas Works at Garston." This, with a report of the discussion, is given on p. 170.

The Balloting List.

The PRESIDENT: I have now to announce the result of the ballot, which was informally communicated to you on Tuesday. The ballot has resulted in the election as President of Mr. J. Ferguson Bell, of Derby. (Applause.)

Mr. J. FERGUSON BELL (Derby): Mr. President and gentlemen, I thank you for the honour you have conferred upon me by my election as President of this Institution. I know it is the highest honour that the gas industry can confer upon any of its members, and during my year of office it will be my earnest endeavour to do everything possible to further the interests of the Institution. If also I can be of service to any of the members individually, it will be an additional pleasure. I feel I can count on the support and the assistance of the Council. In fact, I was told yesterday that if I would only rely on the Council, I should have a very pleasant year. Well, I am going to rely, not only on the Council, but on the whole of the members of the Institution. I am confident that I shall receive the support of the members, otherwise I should have diffidence in accepting the position of President. If I succeed in performing my duties as ably as Mr. Tagg has done, I shall be satisfied that the traditions of the Institution have been maintained. We have a long and illustrious list of Presidents which redounds to the credit of the Institution, and my aim will be to maintain its prestige. I hope that, all being well, in twelve months' time, when I vacate the chair, the Institution will not have lost any of its prestige, and that its influence will not have diminished.

An Invitation to Derby.

The next matter that I have to speak about is this. The Chairman of the Company that it is my honour and privilege to serve, Mr. W. Woolley, came to London to attend the President's luncheon on Tuesday, and on that occasion he extended to you a very hearty invitation, on behalf of himself and his co-Directors, to visit Derby next year. He promised—and I know his promise will be fulfilled—to make as far as possible this visit to Derby an interesting and pleasant one, both to the members and their ladies. I do not suggest that we have all the meetings at Derby; my idea is that we have our business meeting in London, as at present, because London is the Capital; all places converge on London. But we do hope on the last day, when we generally have a visit to some works or some town, that the members will on this occasion in large numbers come to Derby, and we will then do everything we can to give them a pleasant time.

Other Officers.

The PRESIDENT: Proceeding with the ballot, I may say it has resulted in the election of Mr. C. F. Botley, of Hastings, as Senior Vice-President, and he wished me to express his regret at his inability to be present to day. Our Junior Vice-President is Mr. John Wilkinson, of Nottingham. To fill the four vacancies as ordinary members of Council, there have been elected Messrs. C. Dru Drury, of Sunderland; Douglas H. Helps, of Reading; Percy N. Langford, of Coventry; and John Terrace, South Suburban Gas Company, Lower Sydenham. The Hon. Secretary is Mr. W. E. Price; and the Auditors are Mr. Sydney Y. Shoubridge and Messrs. Wood, Drew, and Co. The whole of the candidates for membership and associate membership have been elected.

LIST OF NEW OFFICERS.

President.—Mr. J. Ferguson Bell (Derby).
Senior Vice-President.—Mr. C. F. Botley (Hastings).
Junior Vice-President.—Mr. J. Wilkinson (Nottingham).
New Members of Council (four vacancies).—Messrs. J. Terrace, C. Dru Drury, D. H. Helps, and P. N. Langford.
Hon. Auditor.—Mr. S. Y. Shoubridge.
Auditors.—Messrs. Wood, Drew, &
Hon. Secretary.—Mr. W. E. Price.

New Honorary Members.

There were elected as honorary members of the Institution the Presidents of the Société Technique de l'Industrie du Gaz en France, the American Gas Association, and the Italian Association of Gas and Water Engineers.

Additions to the Roll Members.

The roll of the Institution was increased by the addition of the following names:

MEMBERS.

Allison, Harold Perks, Engineer and Manager, Corporation Gas-Works, Redcar.
Anderson, George Robert, B.Sc., Senior and Resident Assistant Engineer, Bow Common Works of the Gas Light and Coke Company.
Arnold, Barton, Secretary and Manager, Gas-Works, Knottingley, Yorks.
Chew, John Henry, Engineer and Manager, Corporation Gas Department, Blackpool.
Denham, John, Engineer and Manager, Whitehaven United Gas Company.
Dow, Alexander, Engineer and Manager, Galashiels Gas Light Company.
Frost, Frederick Arthur, Works Superintendent, Old Kent Road Station of the South Metropolitan Gas Company.
Furniss, Thomas Edwin, Engineer, Secretary, and Manager, Guisborough Gas Company.
Gardiner, Percy Cyril, Chief Chemist, Tottenham District Light, Heat, and Power Company.
Grey, Alfred William, Assistant Manager, Rochester, Chatham, and Gillingham Gas Company.
Harrison, John Kealy, Manager and Secretary, Armagh Gas Light Company.
Haseldine, John Francis, M.C., Engineer and Manager, Barnet District Gas and Water Company.
Hornby, Thomas, Resident Manager, Hessle Gas Company.
*Ingham, Charles Robert, Engineer and Manager, Corporation Gas Department, Brighouse.
Martin, R. W., Manager and Secretary, Corporation Gas Department, Calne, Wilts.
Norris, William, Manager, Gas-Works, Burgess Hill.
Paterson, Walter Macintyre, Distribution Superintendent, Gas-Works, Bath.
Robertson, Alexander Lockhart, Engineer, Gas-Works, Wigton.
Scott, James John, Engineer and Manager, Gas-Works, Cowdenbeath.

Taylor, Alfred Morrie, Distributing Engineer, Wellington Gas Company (N.Z.).
Twycross, Lionel Edward, Engineer and Works Manager, Gas-Works, Cheltenham.
Wilson, William, Engineer-in-Charge, Berchem Works of the Imperial Continental Gas Association, Antwerp.

ASSOCIATE MEMBERS.

*Alexander Duncan, Engineering Assistant, Tottenham District Light, Heat, and Power Company.
Baker, William James, Chief Assistant, Gas-Works, Margate.
*Bateman, Charles, Assistant Engineer, Cardiff Gas Light and Coke Company.
Bedford, Fred, First Assistant Engineer, Municipal Gas Department, Singapore.
Bisset, Alexander Ronald, Shift Superintendent, Bradford Road Gas-Works of the Manchester Corporation.
Blake, John William, Superintendent (Chemical Works), Corporation Gas Department, Leicester.
Bowden, Reginald, Works Superintendent, Corporation Gas Department, Lincoln.
Collyer, John Cleveley, Assistant Works Manager, Gas-Works, Preston.
Falkner, Robert Streeter, Assistant to Manager and Secretary, Sandown Gas Company (I. of W.).
Gardner, Harold Bellamy, Junior Assistant, Barnet District Gas and Water Company.
Hallam, William Titus, Second Assistant Engineer, Municipal Gas Department, Singapore.
*Levisohn, James Frederick, B.Sc., Works Chemist (Longton), Corporation Gas Department, Stoke-on-Trent.
Lupton, John, Manager and Secretary, Windermere District Gas and Water Company.
Norton, Arthur Leslie, Chief Assistant to Engineer, Redditch Gas Company.
Ralph, John Fisher, Superintendent of Mains and Services, Corporation Gas Department, Leicester.
Rose, John Alexander, Junior Assistant Engineer, Beckton Works, Gas Light and Coke Company.
Rudge, Frank, Assistant Superintendent of Mains and Services, Corporation Gas Department, Leicester.
Simpson, James, Chief Assistant Engineer and Manager, Greenock Corporation Gas-Works.
Smith, Louis William, Assistant Superintendent, Corporation Gas Department, Leicester.
Taylor, Harold, Chemist, City of Birmingham Gas Department.
Taylor, Reginald Charles, B.Sc., Assistant Engineer and Works Manager, Bridlington Gas Company.
*Terry, Charles Donovan, Technical Assistant, Gas-Works, Leamington.
Turnbull, William, Assistant Engineer, Gas-Works, Ilfracombe.
*Wells, Bertram Neale, Technical Assistant, Gas-Works, Margate.

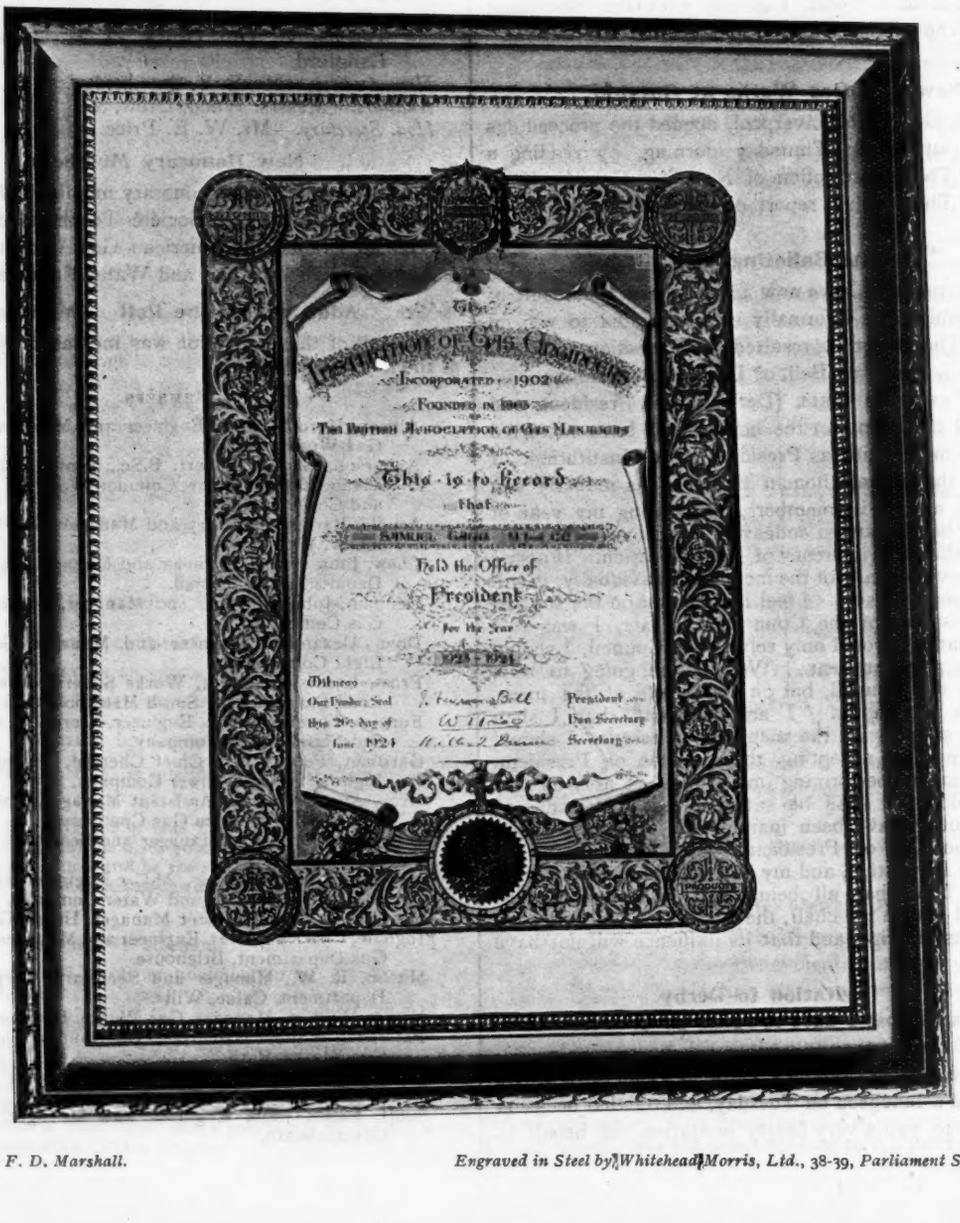
* Formerly a "Student."

ASSOCIATE.

Allan, Eugene Neale, Superintendent, Public Lighting Department, Corporation of Dublin.

Presidential Certificate.

Mr. J. FERGUSON BELL: The Council of the Institution have decided that in future those who occupy the Presidential chair shall, upon the completion of their year of office, be presented with a certificate to record our appreciation of their past services. This certificate, which I think most of the members have seen, has been designed by Mr. F. D. Marshall, at the special request of Mr. Price, our esteemed and energetic Hon. Secretary. I would like to say that Mr. Marshall has designed this certificate as an act of love.



Designed by F. D. Marshall. *Engraved in Steel by Whitehead Morris, Ltd., 38-39, Parliament Street, S.W.*

(Applause.) Mr. Marshall's artistic ability is known to most of the members; but this certificate will, I think, indicate to all that, in doing this work, he has excelled himself, and has produced a certificate which Past-Presidents will be proud to see hanging upon their walls. It is my pleasant duty to ask Mr. Tagg to accept the certificate, which I hope will be a reminder to him of a very pleasant year of office. (Applause.) Mr. Tagg has not only fulfilled the duties of President to the general satisfaction of the members, but he has taken upon himself much onerous work in promoting the best interests of the gas industry. We all wish him continued health and prosperity, and feel sure he will look back with much pleasure upon his term of office, during which he has made many new friends and has retained the esteem and affection of all his old ones. It will be my privilege later to ask those Past-Presidents who are still with us to accept a similar memento of their year of office. There are sixteen of these Past-Presidents, and we on the Council are extremely glad to see, from the attendance at our meetings, that these gentlemen, having passed through the office of President, still retain their active interest in the Institution. The sixteen gentlemen I refer to are Sir Dugald Clerk, and Messrs. John Bond, A. E. Broadberry, W. Doig Gibb, Samuel Glover, Thomas Glover, Thomas Goulden, Thomas Hardie, Charles Hunt, Daniel Irving, Harry E. Jones, Robert G. Shadbolt, James D. Smith, Alexander Wilson, Charles Wood, and my old friend John Young. We hope that they may be long spared and blessed with good health, and that this memento will arouse many happy memories of their connection with the Institution.

The PRESIDENT: I have to acknowledge with gratitude the remarks that have been made by Mr. Bell with regard to my own services. This certificate has been presented to me now, as I happen to be President in the first year since the decision was reached to provide some memento for the Presidents; and speaking for myself—and I believe I shall be able to speak for the other recipients of this very beautiful certificate—it will be a most valued possession. I have seen something of the progress of the design, and desire to associate myself with the remarks that Mr. Bell has made respecting the labours of Mr. Marshall in connection with it. He has spared himself no trouble to produce something which he believes—and believes with justice—will be a source of pride to the Institution. I am very much obliged, and shall value the certificate highly.

Thanks to the Electrical Engineers.

The PRESIDENT: My next duty is to propose a vote of thanks to the Institution of Electrical Engineers for the use of this building for our meeting. This is no formal vote of thanks which I now ask you to pass. The members may not be aware that the Institution of Electrical Engineers courteously placed the building at our disposal for the whole of the week without making any charge. (Applause.) It forms a very striking example of the spirit of unity which is pervading the two industries, and which I hope may yet become stronger. I think the members would desire that the Council should consider if they can in some way recognize this courtesy of the Sister Institution.

Mr. J. FERGUSON BELL: I have very great pleasure in seconding the vote of thanks to the Institution of Electrical Engineers. As the President has pointed out, we owe them a deep debt of gratitude for the use of this building, and we must thank them most heartily for placing it at our disposal. It is an indication of the close association of kindred Institutions, and if we can in any way reciprocate I am sure the members will be only too glad to do so.

The resolution was unanimously carried.

For the Past-Presidents.

The PRESIDENT: I should like to ask Mr. Glover to say a word on behalf of the Past-Presidents regarding the certificate which so far I alone have acknowledged.

Mr. SAMUEL GLOVER: Mr. President, members of the Council, and fellow members of the Institution of Gas Engineers, I must say that I am touched and taken greatly by surprise—a very pleasant surprise—at learning that I, with the other Past-Presidents of the Institution, am to receive a copy of this Presidential Certificate; and on behalf of myself and the other Past-Presidents whose names have been announced to you, I thank the Council for their kind thought, and you for your confirmation of it in such a hearty manner this morning. Anything that keeps us in mind of our close association with the Institution, we most cordially welcome. We thank you for bestowing upon us this handsome memento.

President's Services Acknowledged.

Mr. J. FERGUSON BELL: I am sure you would not like to separate without thanking the President for all he has done for us during his year of office, and also for his conduct in the chair to day and at the previous meetings. As I have already said, Mr. Tagg has exceeded our highest expectations. The office of President of the Institution involves much onerous work, but it must be a source of keen satisfaction to Mr. Tagg to feel, at the end of his year of office, that he has done so well, and has obtained the unanimous approbation of the members. Not only are we indebted to Mr. Tagg, but those of us who were fortunate enough to be present at the reception and the dance given by the President and his wife will long remember that very enjoyable evening. The attendance of members at the business meetings this year has been a record one, and the attendance at the reception furnished another record. Mr. Tagg, in his Presidential Address, set a high note for the meetings, and that note which he began with has been maintained throughout. The meetings this year have been eminently successful, and of a very high standard. I propose that our best thanks be given to the President for his services.

Mr. G. S. FRITH (Runcorn): I have very much pleasure in seconding the proposition of the President-Elect. It has been my privilege to know Mr. Tagg for a great many years. When I was Secretary to the Manchester District Institution, I think I had the pleasure of bringing him forward a little. He was very shy at taking office, but once he got his shoulder to the wheel, he never hesitated. We think very highly of him in the Manchester district. He is courteous on all occasions. I know this vote will be received with acclamation, and am glad Mr. Bell has included Mrs. Tagg in his remarks. We all have very great respect for her, and I think the success of this meeting has been largely due to Mrs. Tagg's charming manner.

Mr. J. FERGUSON BELL: I omitted to say, at the reception I had an opportunity of talking with the Mayor of Preston, and he said to me: "Mr. Tagg is a gentleman." That will be the opinion of the whole meeting. (Applause.)

The PRESIDENT: Mr. Bell, Mr. Frith, and gentlemen, I am exceedingly obliged and touched by your kind remarks, and by the very cordial reception of them. I have had assistance right through the year, and right through this meeting, from the Council and members, and really think that thanks are due from me to them, rather than the other way about. On behalf of Mrs. Tagg, I thank you for what you have said. She will be delighted to know that her efforts have given pleasure, and met with the approval of the members.

Further Votes of Thanks.

Mr. C. V. BENNETT (Rochester): It is my privilege to propose a vote of thanks to the Council. I think this year's programme, if I may say so, has been better than that of any other year. This, and the amount of work the Council have had to do during the past twelve months on other important matters connected with the industry, deserve our hearty thanks.

Mr. W. N. WESTLAKE (Exeter): I am very pleased to second that. We know how representative are the men on the Council, and the great amount of work that their duties involve.

The motion having been unanimously carried,

Mr. C. S. SHAPLEY (Leeds) said: In the absence of Mr. Madden, I beg to acknowledge your hearty vote of thanks to the Council for the work they have done during the past year.

The PRESIDENT: Mr. Bennett, I am sure, wished to include with the Council the Hon. Secretary—of course, he is

the Council—but he may have thought it unnecessary to mention the fact, because Mr. Price is so obviously the mainspring of all the Council's actions. In that vote you do acknowledge his services. (Applause.)

Mr. W. E. Price: I do not think it would be quite right for me to respond for the Council, because I am not the Council, whatever anyone may say. I do my best to keep the Council in the way in which the Institution has been working in past years, and in accord with precedent to a certain extent. I am very pleased to do what I can in that direction without the thanks I get from the members here officially, but I am very, very gratified at the thanks I get from members in the pleased way in which they greet me from time to time when I meet them. If I do not always call to mind a name, it is because it is very difficult to remember the faces of all the members of an Institution numbering over a thousand. But this does not matter. We go on smoothly, and the aim of life is to make things smooth for others as well as for one's self.

Mr. Shapley: The President has asked me to propose a vote of thanks of a very comprehensive character. It is to the authors of papers, who have come forward in a way the Council much appreciate with admirable contributions; to the Research Committees, who have done an enormous amount of work; to the Scrutineers; and to the Auditors. With regard to the Refractory Materials Committee, I should like to refer to the fact that we have lost our Chairman, who has resigned. We are very sorry on the Council that Mr. Broadberry has taken this step, after the valuable work he has done on the Committee. The President has accepted his resignation with great regret, and a letter of thanks is being sent on your behalf by the Council. The work of the Committee will be continued with another Chairman. I do not think I am giving away any secret when I say that I understand Mr. Leather is intending to follow in the footsteps of Mr. Broadberry. I think I have made my vote complete, but I want to add my testimony to the way in which the President has watched over the Research Committees as Chairman. The Committees have had an excellent Chairman, and I for one appreciate the very nice way in which Mr. Tagg has always conducted the meetings.

Mr. W. J. Smith (Bolton): I am very glad to second that. I am pleased it has not been made a purely formal vote, for the work does demand something more than that.

Mr. R. E. Gibson (Liverpool): I think my duty is to return thanks on behalf of the readers of the papers and everybody else, and I have very great pleasure in so doing. You have heard my views at considerable length this morning, and I do not propose to inflict myself upon you any further. We all appreciate this vote very much.

A Wreath at the Cenotaph.

The President: There is just one other matter I wish to mention before we break up. Members will know that a contingent are visiting Paris, to share in the Centenary Celebrations there, and among the duties to be performed by them is that of paying respect to the illustrious Frenchmen who died in the war by placing on the grave of their Unknown Warrior a wreath to-morrow morning; and a very felicitous suggestion was made by Mr. Bennett, of Rochester, that at the same time the Senior Vice-President should place a wreath on the Cenotaph in Whitehall in commemoration of our own countrymen who fell. I hope that as many of the members of the Institution as can make it convenient will attend at the Cenotaph and support the Senior Vice-President in this mark of respect.

The wreath was displayed while the President made these remarks, and the members rose in silence before it. The card attached bore the following:

The Institution of Gas Engineers.

In undying appreciation of the heroism and sacrifice of the Sons of the Gas Industry in all parts of the world, who heard the call to arms. Their dear lives held for Britain her glorious :: :: heritage of freedom. :: ::

"Greater love hath no man than this that a man lay down his life for his friend."

The Secretary.

The President: I should like the members to acknowledge the many services which Mr. Dunn, as Secretary, continues to render the Institution. (Applause.)

Mr. Dunn: I wish just to tell you how very much I appreciate the appreciation which you show of my services. I need hardly say that I could not work as I do if my work was not congenial. It is very pleasant to have one's services acknowledged orally. I think if people would tell one another more what they think of one another, it would be better. Many people would feel happier if others who thought well of them would only tell them so.

The President: That concludes our business.

THE ARTIST.

If he could have written "F.M." after his name instead of "F.D." before it, he would still have been a great success. His enthusiasm, his *bonhomie*, his thoroughness, his technical knowledge—would in combination have carried him anywhere. When in official life, he served well those who employed him; and he was the friend of all who worked under him. He has tried to find out the secrets of things where other men have failed; and in—let us say—low-temperature carbonization he has got nearer the goal than many other men. And when he found that low-temperature carbonization could not commercially stand alone, he said so, and found an appendix to it. The two things in combination would, he alleged, carry us in this matter farther than before. He is interested now in a new coal-distilling process, and plants are going up on a working scale. His professional operations have been largely on the Continent; and during the many years of our friendship he has seemed to have been called practically to every country on the Continent, and even to a place where "nuts come from"—in connection with the carbonization of coal or lignite, or the robbing of the air of its nitrogen for making fertilizers and for other purposes.

We have, as just said, been friends for many years. We have travelled together, enjoyed many hours and good times in company, laughed together and quarrelled; he has instructed me regarding many things in which he has taken a live interest, he has caricatured me—and we are still friends. Of course, he is a gifted artist. He does not look it. There is nothing bizarre about him. He does not wear long hair, or big bows for neck ties. On the contrary, he is smart and debonair. He always was. His work with pencil and brush has appealed to many, and small wonder. He is the designer of the Certificate presented to the President of the Institution (Mr. Samuel Tagg) last week, and of which a photograph is given in this issue on p. 84. It is a very beautiful design; and, to my way of thinking, one of the finest ever produced in this line of art. There is artistic talent in it; and it is a credit to "F. D. M.," and an honour to the Institution. Saying this recalls to memory some fine addresses from the English Colony in Denmark to King Edward, Queen Alexandra, and the Czar of Russia; and several for the Danes to present to distinguished fellow-countrymen. The Committee of the French (Paris) Salon saw the one executed for King Edward, and were so pleased with it that they requested the artist to send it with others for exhibition at the Salon. This was done, and, as far as the one to King Edward was concerned, through His Majesty's kindness in consenting to the proposal, the exhibit gained the Salon's Gold Medal. We believe Queen Alexandra has at Marlborough House one of this artist's water colours of a Danish Royal Yacht steaming in a high sea. This was executed for the ladies of the Court for presentation by them to the Queen on her birthday. That art critic—the Kaiser—had for years in his yacht a water colour which "F. D. M." did for him of the *Hohenzollern* steaming across the Bay of Naples. These are a few of the outlets found for the gift possessed by the gas-engineering designer of the President's Certificate. There are pleasant memories associated with the events. May F. D. Marshall long live to enjoy them, and may his hand never lose its cunning, for the pleasure he has in his work when time permits is the source of admiration and enjoyment by others when the work is completed. A. F. B.

THE PRESIDENTIAL ADDRESS

OF

Mr. SAMUEL TAGG, M.Inst.C.E.,

Engineer and Manager of the Preston Gas Company.

GENTLEMEN,—The Institution of Gas Engineers, representing all the technical officers of the gas undertakings of the country, either directly or through affiliation with the District and Junior Associations, can confer no greater distinction on a member than by electing him as President; and as my association with the industry dates from birth, I appreciate very highly your mark of confidence.

THE MAJORITY OF A UNION.

As the first annual meeting of the Institution was held in 1903, this one may be regarded either as marking the attainment of its majority, or as celebrating the twenty-first anniversary of the union of the Incorporated Gas Institute and the Incorporated Institution of Gas Engineers. The patient and conciliatory efforts which culminated in the fusion effected in 1903 have been rewarded by the contribution the Institution has since made to its essential object as defined in paragraph 3 (*b*) of the Memorandum of Association—viz., "To promote the advancement of the gas industry in all or any of its branches."

A BRIEF REVIEW OF PROGRESS DURING THE TWENTY-ONE YEARS.

A brief glance at the engineering practice during the past twenty-one years reveals steady progress in the general employment of higher carbonizing temperatures, which have been made possible through the use of material of a highly refractory character; in the relief of arduous manual labour by the adoption of stoking machines and plant for the mechanical handling of coal and coke; in the development of the continuous vertical retort system, with provision for the simultaneous production of water gas; through improvements in the design of plant for the separate manufacture of water gas, carburetted or otherwise, or for the complete gasification of coal; and in the adoption of boilers for the application of reclaimed waste heat to a useful purpose.

During the same period, the field of supply has been widely extended by the addition of $3\frac{3}{4}$ million users, attracted largely by the facilities for cooking provided under the prepayment system; while the evolution of the highly efficient fire and the applications of gas to water heating and innumerable industrial operations, have more than compensated for the economies effected by the substitution of the inverted incandescent burner for other and less efficient types, as the increase in the volume of gas sold equals 2·3 p.ct. per year.

It is evident these increased sales are due to new applications as well as to additional users, as the relation of the maximum daily output to the annual output for thirty of the largest undertakings has improved from 1 : 203 to 1 : 251, or, in other words, the load factor has risen from 56 to 69 p.ct.

The recognition by gas authorities of the value of publicity and propaganda work, undertaken with their full co-operation by a central organization, has contributed largely to the appreciation by the general public of the convenience, cheapness, and cleanliness of gas as a fuel; and the British Commercial Gas Association, founded in 1911 for this purpose, has proved an unqualified success.

While the peaceful development of the industry was disturbed by the world war and its aftermath, some consolation is afforded by the recollection that it stood pre-eminent among the essential public services in its response to the stark necessities of the times, and that it realized the opportunity offered of more useful service to the community through the closer union of undertakings, which found expression in the formation of the National Gas Council in 1916.

For an industry of long standing, a notable advance has been made on the technical side through the efforts of many individual workers, including makers of plant and appliances. In this the Institution, in common with other technical bodies, has assisted by promoting the free exchange of views and experience, and by the research work of its Investigation Committee, the results of which have been freely and fully imparted to all concerned, and have proved, and, I am sure, will continue to prove, invaluable to all engaged on the difficult problems awaiting solution.

THE LEGISLATIVE HISTORY OF THE SISTER INDUSTRY.

This cursory survey of recent history would be still more incomplete without a reference to that of the sister service of electricity, which, after some years spent by pioneers in developing plant, apparatus, and cables for the public supply of energy as a commercial proposition, first obtained statutory powers under the Electric Lighting Act, 1882.

At that time the electricity business was regarded as too uncertain to justify the investment of public money; and with the intention of protecting the future interests of local authorities, the concessions the Board of Trade were empowered to make were subject to the following conditions—viz.,

(*a*) That the supply should be confined to the area governed by the municipality.

(*b*) That companies supplying in neighbouring areas should be deprived of the right of association.

(*c*) That the local authorities should have the right of purchasing the undertakings at the end of twenty-one years, paying for the land, buildings, plant, and cables their value at the date of purchase without any allowance for goodwill.

The period of tenure, proving too short to attract capital, was extended in 1888 to forty-two years, with the result that a number of company and, later, municipal undertakings came into being; but the efficiency of the public supply service was impaired by the creation of a large number of undertakings, each operating over areas settled by geographical and political considerations.

With the development of the electric motor, it became evident that small undertakings with limited tenure would not be able to deal satisfactorily with the power business; and in 1898 a Joint Committee recommended *inter alia* that powers should be granted in perpetuity to power companies operating over large areas. But when in 1900 such powers were sought, municipal authorities succeeded in obtaining the exclusion of large towns from the power companies' areas, and in prohibiting them from supplying, without consent, within the areas of existing authorized distributors.

In 1917, the Coal Conservation Sub-Committee in their consideration of the interim report of a Sub-Committee on Electric Power Supply in Great Britain, said: "The historical development of electrical supply in this country during the last thirty years has been local in principle and character, and the resulting position will have to be superseded." In their view, it was scarcely possible to exaggerate the national importance of a technically sound system of electrical supply, which could only be secured by the control of the whole problem of generation and distribution by a central authority; and they recommended the appointment of a Board of Electricity Commissioners, which was eventually established by the Electricity (Supply) Act, 1919.

From the reports of the Commissioners covering the period from January, 1920, to March, 1923, it appears they have constituted Electricity District Boards, which are collectively responsible for the generation of upwards of 50 p.ct. of the public supplies of electricity in Great Britain, and whose duty it is, in the words of the Act, "to provide or secure the provision of a cheap and abundant supply of electricity within their district." They have also sanctioned a gross addition of nearly $1\frac{1}{4}$ million KW. to the plant capacity of authorized undertakers, representing an increase of about 50 p.ct. on the plant capacity in 1920; and they have approved additional loans for local authority undertakings amounting to nearly 37 million pounds.

The average fuel consumption per unit generated throughout the country has progressively decreased during the three years in question in the approximate ratio of 100 : 93 : 83; and the Commissioners state "that such economies serve to

emphasize the importance of the centralization of generation from the point of view of the conservation of fuel."

While the saving effected in fuel is not inconsiderable, the cost of supplying electricity will be further reduced by every additional use which improves the load factor. The advance in this direction is indicated by the returns of the Birmingham, Glasgow, and Manchester undertakings, which show an average rise based on the units sold from 12 p.ct. in 1902 to 21 p.ct. in 1922, while their output for the latter year was sixteen times that of 1902.

The Commissioners declare that the increase in output during 1923, in the case of a number of undertakings, was primarily due to the domestic load; and to encourage the wider use of electricity for this purpose, they favour the adoption of multi-part tariffs. Glasgow, with a two-part tariff, based on a 12½ p.ct. on the net rateable value, *plus* ½d. per unit, had a load factor of 23 p.ct. on the units sold in 1923—an increase of 1¾ p.ct. on the previous year.

A Stimulant to the More Attractive Service of Gas.

The actual and potential progress of the electrical industry will naturally stimulate all concerned in the continued development of the gas industry, as there is abundant evidence that the more attractive service offered by gas in most of the competitive fields will bring additional business if advantage is taken of the opportunities. As the choice between competing supplies which render equal service will depend largely upon their relative cost, it may be of interest to those whose duty it is to advise the undertakings they serve on matters of general policy, to consider some of the principal items included in the charge for gas, commencing with the return on the capital employed.

A Study of Capital and Depreciation.

The position of the companies in respect of capital differs from that of the local authorities, as it is not redeemable, except in special circumstances. The effect of this divergence in practice over a period is shown by a comparison of the capital employed in 1921 by those undertakings whose output then exceeded 100 million c.ft. with that of the same undertakings in 1883—this being the first year for which complete returns are available.

The total capital borrowed by 77 of the principal undertakings owned by local authorities averaged in 1883 £767 per million c.ft. sold, of which £112 had then been repaid, leaving £655 outstanding; the corresponding figures for the same undertakings in 1921 were £568 total capital, less £300 repaid, leaving £268 outstanding. The actual paid-up capital of 128 companies in 1883 averaged £665; and in 1921, £476 per million. But as an average amount of £207 was added during this period by the conversion of shares, stock, and loans, the nominal capital in 1921 was £683, compared with the net indebtedness of the local authorities of £268 per million.

While both classes of undertakings more than trebled their sales of gas during the period under review, about half the additional business was due to the increased demand during the summer months, as the maximum day's output in 1921 was only about double that in 1883. The reduction in the average capital employed per million c.ft. sold was due to this improvement in the load factor, as the capital expenditure per unit of plant capacity in 1921 was higher than that in 1883, owing probably to the outlay incurred in connection with prepayment installation.

The contributions of the local authorities to their sinking funds for repayment of loans between 1883 and 1921 averaged 2½d. per 1000 c.ft. sold; and their total capital charges for 1921 were 7d., compared with 9d. per 1000 c.ft. for the companies—the latter amount representing 5⅝ p.ct. on the nominal capital or 8 p.ct. on the actual expenditure. The unfavourable relative position of the companies raises the question of the provision for the depreciation of capital on which their financial stability will ultimately rest.

As the general practice of statutory companies has followed the form of accounts in Schedule B of the Gas-Works Clauses Act, 1871, it may be assumed that the cost of all renewals as they have fallen due has been charged to revenue, with the possible exception of such items as gas-holders, involving large expenditure which could not conveniently be met over short periods. But if the total cost has been so charged, the provision for depreciation remains inadequate to the extent of the continued wastage of all assets until their replacement is effected.

If the companies had been under an obligation to set aside each year from the date of their formation an amount sufficient to meet the cost of replacing plant at the end of its estimated life, the balance that would now be standing to the credit of such funds, after providing for all renewals that had fallen due, would equal approximately one-half of the total capital expended.

In the absence of such provision by Parliament in the early years of the companies' existence, while the useful life of the various items of plant was maturing, the reserves which in one form or another have been created, including amounts applied out of revenue for capital purposes, appear insufficient as a whole, especially as the cost of renewals will continue largely in excess of the cost of existing plant for an indefinite period.

To maintain a long-established industry in a sound financial condition, the profit earned should be sufficient to meet the inevitable depreciation in the value of its assets due to wear and tear before providing a reasonable return on the capital employed; and for a competitive technical business there should be a further margin available for the replacement of plant when rendered obsolescent by the invention or development of a more efficient or economical type.

This is evidently realized by the Metropolitan electrical companies, as they applied 46 p.ct. of their profits in 1922 to this purpose, or to other reserve accounts, representing a depreciation of 6·3 p.ct. on their total capital of 19 million pounds. The local authorities are achieving the same end by liberal annual contributions to their sinking funds; the amount so applied by the Birmingham, Glasgow, and Manchester undertakings for the last financial year being equal to 4·2 p.ct. on their total capital. In this connection the following extract from the second report of the Electricity Commissioners is of interest: "Where the financial position of an undertaking justifies such a course, the charging to revenue of recurring expenditure, such as that of services and for short-lived assets such as meters, is a practice to be commended on financial grounds."

Although the question of adequate depreciation is one of importance, no useful purpose would be served on this occasion by an attempt generally to define the form it should take, as this will necessarily depend upon local circumstances and existing statutory powers. But there can be no doubt that some companies could with advantage make further provision out of revenue, unless they are working under a sliding-scale, and prefer to apply surplus profits to this end, instead of paying dividends in excess of the standard.

Coal, Oil, and Wages.

Turning to other essential items of expenditure, there is little prospect of a reduction in the cost of coal; and, indeed, an increase appears more probable. The uncertainty regarding the future supplies of gas oil, and the recent advances in price, tend to make this material less attractive from an economical standpoint, except for use in emergencies, or to meet peak loads over short periods.

The friendly relations which have been established with labour have facilitated the reasonable adjustment of wages in accordance with the cost of living; but no substantial reduction can fairly be looked for in the near future, although, in view of the large proportion of manufacturing and distributing costs represented by labour charges, it is essential that the rates of pay shall be closely related to those in other industries of a similar character.

The Present Status and Future of Coke.

As little or no immediate relief may therefore be expected in the cost of standing charges, raw materials, or labour, the prospect of further reductions in the price for gas (which is generally low in comparison either with pre-war prices, or the cost of alternative sources of heat energy) appears to lie in an extension of business, in increased values for the secondary product coke, and in higher production efficiencies and economies.

Before the war, the supply of coke exceeded the normal demand; and the disposal of the surplus quantity usually involved a general reduction in price to a point below its value compared with other fuels. In 1913, when the total quantity available for sale was approximately 8·3 million tons, the average price realized by undertakings representative of the whole country was only 72 p.ct. of the price of gas coal.

In 1922 the total quantity of coke made for sale had fallen to 7·2 million tons, of which over 900,000 tons were exported. Although the returns of production for last year are not yet

published, the exports exceeded 1,200,000 tons; and it is therefore probable that the total coke available for home sale in 1923 was about 6 million tons, compared with 7·4 million tons in 1913.

The higher prices obtained for coke last year were in many cases equal to the price of coal; and the increased revenue from coke enabled general reductions to be made in the price of gas, whereas an increase of about 15 p.ct. on current prices would have been required to produce the same total revenue received by undertakings making coal gas only if the ratio of coke and coal values in 1913 had continued unchanged.

The lessened production of coke for sale, despite the growth in the demand for gas, is explained by the general supply of a calorific value below the pre-war standards, as it may be assumed for all practical purposes that for each 1 p.ct fall effected in the calorific value of a good coal gas by the addition of blue water gas, the coke remaining for disposal is reduced by 3 p.ct., and thus a drop in value from 560 B.Th.U. to 480 B.Th.U. would reduce the quantity of coke for sale by 42 p.ct. This ratio is based upon an efficiency for water-gas production of 120 therms per ton of coke, and does not apply to the more economical method of steaming vertical retort charges. But the reaction of this practice on the coke available for sale is illustrated by the returns of the Carlisle undertaking, which show a reduction from 23,353 tons in 1921 to 10,972 in 1924.

As the reduction in the net cost of coal gas promoted by higher coke values will tend to its increased production in place of water gas, the balance of the supply of, and the demand for, coke may have to be maintained by the development of new markets, and preference should be given to those in which it displaces fuels of higher value rather than the cheaper low-grade fuels for steam-raising. The annual output of anthracite only amounts to about 5 million tons, of which nearly half is exported in some years; and as gas coke is the only alternative fuel at the present time for those purposes for which bituminous coal is unsuited, its value—having regard to its smokeless character and high radiant efficiency—should approach that of anthracite. The replacement of coal in the open domestic grate offers the most attractive market for coke, both in the national interest and from the point of view of the industry, as about 40 million tons of coal are used annually for household purposes. In its present form, coke cannot altogether be regarded as a satisfactory substitute for use in existing grates, owing to its high ash content and ignition temperature. Besides, the relatively small amount of air passing through the fuel bed is often insufficient to promote free combustion, or prevent the occasional escape of sulphur compounds into the room; and a modification of the structure or composition of coke or specially designed grates are desirable, if coal is to be superseded to any considerable extent.

Public opinion is slowly awakening to a recognition of the evils attending the emission of smoke, and to the injury to health and the general wellbeing of the community through the interference with the direct rays of the sun by the smoke pall over large residential and industrial areas. The gas industry has rendered valuable service to the nation by developing the use of gas and coke in place of coal, and so reducing the evils arising from smoke. These will ultimately be entirely avoided if the industry can accompany the extended applications of gas with the supply of a solid smokeless fuel which will compete in price with coal, and prove as attractive in use.

Production of Solid Smokeless Fuel.

An immense amount of laboratory research and small and large scale experimental work has been undertaken in this and other countries in the attempt successfully to solve the problem of the commercial production of a smokeless fuel by low-temperature carbonization methods, and many processes of promise have been evolved.

In the Maclaurin process, the distillation is effected by the sensible heat of producer and water gas generated within the retort. Its financial success depends largely upon finding an outlet for the large volume of low-grade gas produced; and with interest we shall await the experience of the Glasgow Gas Department, who are installing plant of this type, for the supply of fuel gas to the Electricity Department.

In other processes in which distillation is effected by external heating, about 30 therms of rich gas are obtained per ton of coal carbonized, for which Lander and M'Kay, in discussing the economics of the problem, assume a value of 4d. per therm. It is difficult to conceive of demands other than those of the gas industry which would regularly absorb any considerable volume at this price; and for this and other reasons, it is almost certain that, if the smokeless fuel of the future proves to be a low-temperature product, its manufacture and supply will pass into the experienced hands of the gas industry.

E. V. Evans, in his admirable Cantor Lectures, has shown that rapid carbonization is essential for high gaseous thermal yields. He and other workers have pointed out that the formation of the plastic layer within the coal charge, which retards the rate of heat transmission, can be avoided by the addition of an inert material such as coke—the coal-coke mixture being ground and briquetted under pressure without the use of a binder. He draws the attention of the industry to the opportunity awaiting it in the supply of a smokeless fuel, and makes the interesting suggestion that this may be obtained by arresting the high-temperature distillation of coal-coke briquettes at a stage at which about 5 p.ct. of volatile matter remains equally distributed throughout the dense small-celled coke. E. C. Evans and E. R. Sutcliffe had previously successfully developed this method of pre-treating coal in their low-temperature process—producing a solid fuel of high density, and possessing a high degree of combustibility, much superior to ordinary gas coke.

It is suggested that it may be possible to secure some of the advantages of the coal-coke briquetting process, and avoid the use of inert material, and the cost of grinding and briquetting the mixture, by conducting the distillation of coal in two super-imposed continuous vertical retorts. The coal would be passed through the primary retort in thin layers by mechanical means, and low-temperature distillation be effected by the sensible heat of the gases leaving the secondary retort, supplemented, if necessary, by the external application of waste gases. The carbonization of the partially fused coal would be completed in the high-temperature secondary retort, and the cementation of the charge be realized without the formation of the large-celled coke structure which it is desired to avoid. This principle in one form or other, and for various reasons, has been applied in low-temperature processes, and by T. R. Wollaston in connection with gas-producers designed to increase the availability of low-grade fuels by preliminary coking, or to facilitate the use of coke breeze by expelling excess moisture. Large producers of this type are now under test.

The Trend of Practice.

At the present time, practice is tending in the direction of the single-stage total gasification of coal, and the partial gasification of coke by steaming the coal charge during distillation, or the separate production of water gas. The thermal value of the gaseous product under these conditions will range from 450 B.Th.U. to 500 B.Th.U., while the value of the coke remaining for disposal will be enhanced by the reduction in the quantity available for sale. The alternative policy lies in the pre-treatment of coal to increase the rate of carbonization, reduce the cost of manufacture, and produce a coke of such a character that it will be freely used in substitution for coal, and so command a wide and remunerative market, while the thermal value of the gas will range from 500 to 550 B.Th.U.

Research and Its Development.

Much research and experimental work is required before the respective merits of the various processes can be definitely established; and as few undertakings possess the resources essential for such investigations, it appears a favourable opportunity for the Institution to extend the scope of its Investigation Committee's work under the guidance of the University of Leeds. The experimental carbonizing plant presented to the University in memory of the late Sir Corbet Woodall is available; and no question of cost should delay work which promises to be of great value to the industry.

For some years the pressure of industrial and economic issues has interfered with the technical progress of the industry; but with more stable conditions, and the rapid growth of the electrical industry, attention will again be directed, and with renewed energy, to increasing the efficiency of all processes involved in the manufacture of gas. In this connection, the reports of the Gas Investigation Committee will prove of great assistance; and particularly

hose relating to steaming in vertical retorts, water-gas production, and recovery of waste heat. Their value would be extended to a wider circle of workers by the preparation of a summary of essential results and conclusions, coupled with such deductions affecting ordinary working conditions as may safely be made.

While the work of the Fuel Research Board in connection with the physical and chemical survey of the national coal resources, standard methods of sampling and analysis, and other investigations of a general character, are of value to the gas industry, in common with others concerned in the utilization of fuel, the Board are rendering further and particular service by their co-operation on other questions of national importance relating solely to high-temperature carbonization. Among these may be mentioned investigation on the steaming of Durham and Welsh coals in vertical retorts, the effect of the admission of air to the base of the retort, an examination of temperatures throughout the coal charge, the effect of the calorific value of the injection of oil, and radiation losses from vertical retort settings.

PRACTICAL METHODS OF ASSISTING PROGRESS.

In addition to the research work of their Committees, the Institution are contributing to the elucidation of technical problems by the submission, consideration, and discussion of papers of a character similar to those to be presented at this meeting. As the opportunity for discussion on these occasions is necessarily limited, the District Associations could assist by obtaining supplementary papers on the same subject, or by making provision for their members to continue the discussion on the original paper. Co-ordination in this direction could be usefully extended to the Junior Associations.

Progress in the design of plant and manufacturing methods would be facilitated by the systematic return by individual undertakings of information on all matters on which accurate and reliable data would be of value for comparative purposes —such as working results and costs of various processes, and the life and behaviour of materials. The Institution could act as a clearing-house for the collection, tabulation, and publication of such information. Another direction in which the Institution could move with advantage to the industry is in the standardization of the dimensions, form, and quality of component parts in common use. The main object of this work would be the elimination of the waste of time and material involved in the production of a variety of sizes and qualities for one and the same purpose, and to secure interchangeability, while avoiding any interference with the design of the complete apparatus, machine, or plant. The Institution have already done valuable work of this character, as for example in the joint preparation of the Standard Specification for Refractory Materials completed last year. The determination of standard dimensions for retort sections would be the logical sequence of this work. An immense amount of useful standardization and unification has been accomplished in many industries through the various Committees of the British Engineering Standards Association; and, as an illustration, it may be mentioned that the number of tramway rail sections has been reduced from 75 to 4.

A DIRECTOR OF THE INSTITUTION'S TECHNICAL ACTIVITIES.

Any increase in the activities of the Institution as suggested would involve the appointment of a technical officer, who should be a gas engineer of experience. In any event, the services of such an officer would be invaluable to the Institution in its capacity as technical advisor to the other organizations of the industry, and in the assistance he could render to the standing Technical Committees.

CO-OPERATION OF USER AND MANUFACTURER OF PLANT AND APPLIANCES.

The motive underlying the desire to improve the efficiency of all processes involved in the manufacture and supply of gas is to give a better and cheaper service to the user, and so increase the demand; and as this is equally the object of the manufacturer of plant and apparatus, the fullest opportunity should be afforded for co-operation on technical matters. The knowledge and experience of those responsible for the continued operation of plant, or for the supply and maintenance of appliances on the district, are absolutely essential to those engaged in the design and manufacture, and equally a fuller appreciation of the manufacturers' difficulties would frequently assist the buyer in finding a solution.

The Institution seeks the co-operation of the manufacturers on the Joint Committee formed for specific purposes; but a permanent bond between technicians appears desirable, provided complete freedom of action is retained in those spheres where interests are not identical. If mutually desired, such permanent relations could possibly be established by the formation of a technical section of the Society of British Gas Industries affiliated with the Institution in like manner to the District Associations.

THE EDUCATION SCHEME.

The Institution is to be congratulated on the success which has attended the labours of the Committee in their introduction of the Education Scheme approved by the general meeting convened for that purpose in February, 1923. The scheme provides an organized course of study designed to assist those entering the industry to acquire a fundamental knowledge of the theory and practice of the sciences on which the art of manufacture and supply of gas is based; and the student taking advantage of the facilities offered by the complete course will gain a well-balanced mental equipment of the highest value for his future work.

For the successful inception and application of the scheme, the Institution is mainly indebted to the sustained inspiration of F. W. Goodenough, the unquenchable enthusiasm of Walter Hole, and the synthetic sympathy of the representatives of the Education Departments. The Council propose that the winning of the Diploma shall be further recognized by the Institution, by qualifying the holder for admission into the class of Associate Members if under 24 years of age, and into the class of Members if over this age, provided he holds some responsible position in the engineering department of a gas undertaking.

The sure and certain road to progress lies in the better education and training of the younger men on whom the efficiency of operations now largely depends, and who will in the future be called upon to accept the responsibility of full control. The scheme has aroused wide-spread interest among the Junior Associations; and, with the assistance of members of this Institution in encouraging and providing facilities for prospective students, its successful working is assured.

THE SUPPORT OF THE INDUSTRY.

For this, and for other work directed to the development of the essential public service of supplying gas, which the Institution may undertake, further financial assistance may be required; but there is little doubt this will be forthcoming in view of the support consistently extended by those responsible for the administration of the industry towards every collective effort made for its advancement. This has been strikingly illustrated by the magnificent response to the appeal for the co-operative exhibit at Wembley, which will impress the public by its very complete revelation of the capacity of gas to serve the manifold domestic and industrial needs of the community.

DUTY AND PROGRESS.

For the fulfilment of this promise, technical progress and publicity are alike essential; and the Institution may be relied upon to discharge faithfully the function to which reference has previously been made—viz., to promote the advancement of the gas industry in all or any of its branches, and for the benefit of mankind.

The bond of common interest present in nearly every phase of the activities of undertakings, large and small, will lead to their closer relationship, and accelerate the progress which has been a distinguishing feature of the history of the industry for the past century.

Employees enjoying the advantages of co-partnership will continue to share in its prosperity, and more employment of a permanent and less laborious character will be created, with additional security, under prudent administration, for the capital necessary for its development.

The wider and more general use of the products of carbonization will reduce the prevalent smoke evil, conserve the valuable coal supplies of the country, and further benefit the community, by improving domestic amenity and industrial efficiency.

The efforts of all engaged in this responsible and important work will be quickened by the knowledge that, in serving the industry they are proud to be associated with, they are truly serving their times and generation.

ELEVENTH REPORT OF THE RESEARCH SUB-COMMITTEE OF THE GAS INVESTIGATION COMMITTEE OF THE INSTITUTION OF GAS ENGINEERS.

AERATION AND AIR INJECTION.—PART II.

Adopted by the Gas Investigation Committee, June 4, 1924.

RESEARCH SUB-COMMITTEE.

Chairman: Emeritus Professor Arthur Smithells, C.M.G., D.Sc., F.R.S.

Representatives of the University of Leeds: Prof. J. W. Cobb, C.B.E., B.Sc., F.I.C. (Hon. Secretary), Prof. J. B. Cohen, Ph.D., B.Sc., F.R.S., and Mr. G. R. Thompson, B.Sc. (One vacancy.)

Representatives of the Institution of Gas Engineers: Messrs. J. Bond, O.B.E., T. Glover, C.B.E., M.Inst.C.E., H. Pooley, M.Inst.C.E., S. Tagg, M.Inst.C.E., C. Wood, O.B.E. Mr. T. F. E. Rhead, M.Sc., was co-opted a member of the Research Sub-Committee for the purpose and period of research work at Birmingham, and Mr. C. S. Shapley for the purpose and period of research work at the Leeds Gas-Works.

Research Chemists: James W. Wood, M.Sc. (Tech.), A.I.C., on the relative efficiencies in use of different grades and compositions of gas; A. Parker, D.Sc. (Birmingham), M.Sc. (Manc.), F.I.C., on the comparative economies in production of different grades of gas.

Research Assistants: Messrs. H. Kerr, A.I.C., Diploma Fuel and Metallurgy (Leeds), G. B. Howarth, M.Sc., Gas Engineering (Leeds), A.I.C., and A. C. Monkhouse, Ph.D. (Leeds), B.Sc., A.I.C.

GENERAL INTRODUCTION

The Joint Gas Heating, Lighting, and Ventilation Research Committee of the Institution of Gas Engineers and the University of Leeds has continued to act as the Gas Research Sub-Committee of the larger Gas Investigation Committee. Its constitution is given above. The Committee feels itself fortunate in that, although Prof. Smithells has completed his term of distinguished service as Professor of Chemistry at the University of Leeds, he has retained his Chairmanship of this Committee. During the year, Mr. H. Pooley, of Leicester, has taken the place of Mr. H. E. Bloor, of York, who, to the regret of the Committee, found that pressure of other duties compelled his resignation.

The work carried out during the year under the supervision of Prof. Cobb has not been so much on new subjects as on logical developments of investigations already in hand and partially completed.

The Ninth Report described in detail a number of experiments which had been carried out by Mr. James W. Wood and his assistant, Mr. G. B. Howarth, on aeration in atmospheric burners and air injection. These experiments were deliberately made with the simplest possible appliances under the least complicated conditions of operation, in order to see how far it was possible to deduce any general rules or formulæ applicable in such cases. It was always in mind that extension of the results to the problems of practice arising in the design, construction, and operation of burners would be made so far as was found legitimate. During the past twelve months a careful examination has been made of the aeration accompanying the use of gas in several typical burners—ring burners and those of the gas-fire. The influence on aeration of varying the gas pressure and of altering the specific gravity was examined, and the difference brought about by the burner casing warming up in use. It has been found possible to deduce some working rules (see Summary, Eleventh Report) which it is hoped will prove of service in practice, apart from their scientific interest. This is the more gratifying since a careful and critical examination of previous publications on the subject had not proved fruitful of results, in some cases because the method of treatment had been, for perfectly legitimate ends, made too theoretical to allow of direct application to practice, and in other cases because the work had been vitiated by premature and hasty generalizations. It may be also stated here in justice to Mr. Wood, that some portion of the work has had to be carried out single-handed, because of the necessity of transferring the services of Mr. Howarth, his assistant, during test periods to Dr. Parker.

The other main branch of work which has occupied the attention of the Committee has been that carried out by Dr. Parker and his assistants, Mr. Kerr and Dr. Monkhouse, in investigating the performance of waste-heat boilers attached to continuous vertical retort settings at Birmingham. Figures had already been obtained showing what economies were being gained and might be expected, and what increase in thermal efficiency of gasification might result, from the attachment of a waste-heat boiler to a water-gas plant. It was plainly desirable to do the same thing for the process of carbonization as conducted in retorts, and a typical installation was chosen for the purpose. In order to carry out this investigation properly, it was found advisable to do far more than might appear at first sight necessary, and Dr. Parker has made a thorough study of a number of effects which influence the results obtained, and has made, as far as possible, a quantitative estimate of these disturbing factors.

During the year a communication which had been offered to the Gas Research Sub-Committee, and which they were very pleased to accept, was made from the laboratories of the South Metropolitan Gas Company with the permission of Dr. Carpenter. It was so made and accepted with the view of saving duplication of work on a subject of great interest to the gas industry—namely, the practicability of replacing some of the carbon monoxide of water gas and coal gas by methane. The Gas Investigation Committee, on the advice of the Gas Research Sub-Committee, has recommended publication of this interesting and valuable communication.

The Committee would like to place on record once more its great appreciation of the facilities which the Birmingham Corporation Gas Department, through its General Manager, Mr. A. W. Smith, has continued to provide during the current year, more especially since the work in Birmingham has now been completed for the time being. This appreciation also extends to the willing co-operation of the Staff of that Department, Mr. J. Foster (Chief Engineer), Mr. T. F. E. Rhead (Chief Chemist), and Mr. G. A. Bamber and Mr. G. C. Pearson, of the Adderley Street and Windsor Street works respectively.

Thanks are also due and tendered to the Leeds Corporation Gas Department and its General Manager, Mr. C. S. Shapley, who have housed Mr. Wood and his assistant for the purpose of their work at the Meadow Lane Gas-Works, and have provided facilities in connection with it.

Finally, the Committee would like once more to express its high appreciation of the resource and skill which have again been brought to bear upon the work by its staff, and particularly by the chief Research Chemists, Mr. James W. Wood and Dr. A. Parker, who have been immediately responsible for the investigations into aeration and waste-heat boilers respectively.

This year has seen the completion of the experimental gas plant erected by Mr. Henry Woodall with the co-operation of some friends as a memorial to his father, the late Sir Corbet Woodall. The plant was formally handed over to the University of Leeds at an opening ceremony on March 17, and will, it is hoped, prove of great service to the gas industry. Dr. Parker and his staff have now come to Leeds in order to make use of this unique and valuable addition to the resources of the University in forwarding the work of the Gas Investigation Committee.

AERATION OF BURNERS.—PART II.

Summary.

The investigation of the conditions controlling the aeration of burners, which formed the substance of the Ninth Report of this Committee, has been continued by a more detailed study of the aeration conditions in typical ring burners, and in a gas-fire.

Gas Rings.

A complete series of aeration tests has been carried out in the case of each of two typical drilled ring burners of different patterns. Throughout the tests they have been worked at various gas rates and pressures with the same "fixed" nipple, and without any alteration or adjustment of the air inlets.

The burners were first tested with the gas unlighted.

Gases of specific gravities 0·4, 0·5, and 0·6 have been used at pressures up to 3 in. water gauge, and gas rates up to 25 c.ft. per hour. Another series of tests was made with gas of specific gravity 1·0.

With regard to the application of the results summarized below, it is clear that it would be unwise to generalize as to quantitative relationships among the various conditions involved, from data obtained with only two burners. On the other hand, it is believed that the burners were representative of one large class of domestic appliances, and were used under typical working conditions. It is highly probable, therefore, that the data indicate at least approximately the order of the changes in aeration which may be expected with such appliances in practice, and may be to that extent a useful guide.

For gas of any one quality the air-gas ratio increased very rapidly with pressure at low pressures, but the further increase in aeration at gas pressures above 1 in. water gauge was relatively small, being less than 10 p.ct. in all tests, and with the shorter of the two burners less than 5 p.ct.

Both at equal gas rates and at equal gas pressures the air-gas ratio always increased when the specific gravity of the injecting gas was increased.

For gases of different specific gravities, the air-gas ratio was, however, definitely not simply proportional to the specific gravity of the gas, whether comparisons were made on the basis of equal pressures or equal gas rates.

If comparisons were made at equal gas pressures (for either burner) the rate of air injection in c.ft. per hour was approximately the same for all the gases tested, *i.e.*, independent of specific gravity. (Compare item 4 of Summary of Ninth Report, p. 177, reprinted below.)*

Since at equal pressures the gas rate was approximately inversely proportional to the square root of the specific gravity, this means that at constant pressure the air-gas ratio was nearly proportional to the square root of the specific gravity of the gas.

If attention is confined to the specific gravity range 0·4 to 0·6, the above relationship can be simplified thus:—The percentage change in air-gas ratio is one-half the percentage change in specific gravity for equal jet pressures—*e.g.*, for an increase of 10 p.ct. in sp. gr. (say) from 0·48 to 0·53, the air-gas ratio would increase by 5 p.ct., or from (say) 3·00 to 3·15.

Owing to the fact that the change in air-gas ratio was small over the working pressure range of the burners (say 0·5 — 3·0 in. water gauge), the relation given in the preceding paragraph also applies for these two burners to comparisons made at equal gas rates.

The influence on aeration of lighting the burners and allowing them to become hot in use was then separately examined.

In the case of ring burners working under ordinary conditions of use, the mere act of lighting the burner produced no measurable effect upon the degree of aeration.

When the burners had been in operation sufficiently long to become hot, there was a reduction in air-gas ratio as compared with the cold burner working with the same gas quality, rate, and pressure, which differed with the type of burner used.

For the short shank burner the reduction in air-gas ratio was about 10 p.ct.
For the long shank burner the reduction in air-gas ratio was about 15 p.ct.

From special consideration of experiments made with the gas-fire when hot and when cold, and from general consideration of the factors involved, it would appear that the conclusions arrived at with regard to the change in aeration with specific gravity and gas pressure for cold unlighted burners might be applied with some confidence to the same burners when in their normal working state. Further experiments on this point are contemplated.

Gas-Fires.

The aeration curves for a typical 14-in. gas-fire were determined, and showed similar characteristics to those of the gas rings, except that beyond 1 to 1½-in. water gauge there was a slight reduction in air-gas ratio as the pressure was increased, the gas-fire being tested with the gas unlighted.

These characteristics were retained when the fire was lighted, but the air-gas ratio fell by about 10 p.ct at all gas rates and pressures, within the range examined. This reduction was smaller than was anticipated from the tests with the gas rings, and it is probable that the chimney pull produced by lighting the gas in some measure compensated for the reduction which might be expected to result from heating-up the burner body.

Introduction.

The presentation of the Ninth Report of the Gas Investigation Committee marked a stage in the investigation of aeration and air-injection problems.

As detailed in the early part of the Ninth Report, experiments were made with injection apparatus of a very simple character. The results obtained, however, showed that even for such apparatus the problem of air injection is very complex, and few simple quantitative relations among the various factors, such as dimensions of the apparatus and gas rate, pressure and specific gravity, could be formulated. It was believed that results of greater immediate value might be obtained by continuing experiments with actual gas-burners, under suitably chosen conditions, following on those already given in the Ninth Report (p. 206 *et seq.*).

Before doing so, however, a further search of available literature was undertaken to see whether other workers had been able to put forward any reasonable theory of injector action in gas-burners, applicable to practice, or to suggest methods of investigation superior to those we had developed for the purpose, and which might be adopted for facilitating our research.

So far as Continental literature is concerned, a bibliography was prepared and published in the final copies of the Ninth Report of the Gas Investigation Committee (pp. 227-9) and is republished here (Appendix I.).

In none of the papers examined was the theoretical and experimental treatment sufficiently complete to establish any general theory of injector action which could be usefully applied to the requirements of practice. Further, the conditions under which the various burners were operated differed in such a marked degree from one another and from current practice in this country, that empirical relations between aeration and gas rate, pressure, or specific gravity, which in some cases might have been deduced, would not have provided any useful basis for controlling burner operation under prevailing English conditions.

The most noteworthy paper is, perhaps, one by H. Pfotenhauer upon "The Bunsen Burner as a Gas Injector." It is in the main a mathematical treatment of the aeration problem for the simplest types of Bunsen burner, and is remarkable for the very large number of factors which the author has endeavoured to take into account and to treat quantitatively. In consequence, the formulæ developed become exceedingly complicated and are very limited in their application. Some experimental evidence is put forward which it is claimed gives confidence in adopting the formulæ. A careful consideration of the possibilities of the experimental instruments and methods adopted, however, would make one hesitate to regard the theory and formulæ either as established or disproved, as the data obtainable could not be expected to have the accuracy which would be necessary for a crucial test.

In another direction we have carried out further tests in connection with the supply to burners of directly metered quantities of gas and air, as outlined in our Ninth Report, p. 183. It has not been possible to procure a suitable blower or air compressor capable of delivering air at the rate of 50 to 250 c.ft. per hour, with a very steady outlet pressure, and

* (4) It was found to be strictly true in certain cases, and approximately so in others, that if the same injection tube and gas nipple were used, but the specific gravity of the gas increased, for the same gas pressure, the volume of air drawn in was unaltered—*i.e.*, the air-gas ratio was inversely proportional to the gas rate. To what extent a useful generalization can be made in this connection cannot be said without further investigation.

to meter this air and govern down the pressure so that there should not be a fluctuation of more than a few thousandths of an inch water gauge in the chamber surrounding the injector. This method of working, which in other respects possesses considerable merits, has had therefore to be abandoned.

When the tests of the present report were well in hand, newly published papers* by Dr. J. S. G. Thomas, Senior Physicist to the South Metropolitan Gas Company, were brought to our notice, describing a hot-wire anemometer by means of which aeration measurements had been made rapidly and with considerable accuracy. Through the kindness of Dr. Carpenter, Prof. Cobb and Mr. Wood inspected the apparatus and discussed the investigation with Mr. E. V. Evans and Dr. Thomas. The sequence of our tests was interrupted to investigate this new apparatus, and experimental work carried out in connection with it. It is only necessary to point out at this stage that the apparatus does not appear to be suitable in its present form for measuring the degree of aeration of domestic gas appliances which take from 15 to 50 c.ft. of gas per hour. Some modification of the dimensions of the anemometer and of the method of using it may eliminate the defects encountered and provide a satisfactory instrument for aeration measurements of the kind with which we are concerned.

After careful consideration of such information as was available with regard to the aeration of burners, it seemed that no satisfactory solution of the many problems arising had yet been reached, and that there was in consequence good reason for continuing our investigations, utilizing the methods which we had already devised. The plan of attack on the problem was, however, modified, work being directed towards obtaining answers to specific questions such as arise in connection with gas utilization, rather than to a general solution.

EFFECT OF CHANGE OF SPECIFIC GRAVITY UPON DEGREE OF AERATION.

Possibly the commonest problem in gas utilization is that of the appliance which has been specially adjusted for a local gas supply and is not provided with any means whatever by which this adjustment can be readily altered.

The first series of experiments was directed to ascertaining how such an appliance would behave as regards its degree of air entrainment, under the influence of changes in gas rate and pressure, as the specific gravity of the injecting gas was varied step by step. In general the apparatus and methods used were those already described in the Ninth Report.

Tests were made with a typical drilled ring burner of the cooker hotplate type, the burner used being the short shank ring burner of the Ninth Report † used in conjunction with jet D of the same report. This combination would allow the burner to work at suitable gas rates within the pressure range 1 to 3 in. water gauge. No air-restricting device of any kind was employed. Particulars of the burner, which is illustrated by fig. 1, are given in Table 1.

The tests were made in the manner indicated in the Ninth Report, this method having the great advantage that the free or natural operation of the burner is not affected in any way during the test. The gases to be experimented with were stored in a 200 c.ft. holder in turn, and were metered to the burner at selected gas rates and pressures. For each set of conditions, the air-gas ratio was determined by withdrawing samples of the mixture formed in the burner and subjecting them to chemical analysis. Judged by the concordance of duplicate analyses of the same sample of mixture, the method is accurate at least to ± 1 p.ct. of the air injected for typical mixtures with an air-gas ratio of 4 : 1 or less. On the other hand, successive samples taken under conditions supposed to be identical occasionally yielded results differing by about 2 p.ct. Thus the air-gas ratio fluctuates slightly, and this may be attributed to slight draughts about the air intake or burner outlet, and in a smaller degree to fluctuations in gas rate. As the usual time taken in collecting a sample was about 3 to 5 minutes, small irregularities in aeration are averaged out. In the case of short burners, there is some risk of contamination of the air supply with mixture which has already passed through the burner. The air at the intake to the burner was therefore sampled simultaneously with the mixture and analyzed, and its composition taken into account in calculating the air-gas ratio. With very low CO_2 content of the mixture, the determination of, and allowance for, the CO_2 normally present in the air becomes important. The larger Haldane apparatus was used for this purpose.

The present series of experiments was made with the burner cold, and the effect of lighting the burner is separately studied at a later stage. It is believed that testing the burner cold has certain advantages. The main advantage is that the condition of the burner is more stable and can be defined with greater certainty, and it becomes possible to eliminate all thermal considerations and treat the appliance, firstly, as a mechanical device for producing an air-gas mixture, quite apart from its use as a burner, and afterwards to treat it as a burner. The recognition of these different aspects of the case is important when considering the design of a burner.

Tests were made at selected gas rates and pressures with gases of specific gravities 0·4, 0·5, and 0·6, thus covering a range of conditions as regards specific gravities rather wider than that normally encountered in town gas practice. The gases of specific gravity 0·4 were obtained from the 1/100 ton experimental coal-gas plant at the Meadow Lane Gas-Works of the Leeds Corporation. The residue of gas from the first set of experiments was mixed with a suitable proportion of air to yield a gas of specific gravity 0·5. The exact amount of air added was determined by analysis, and the composition and specific gravity of the mixture were calculated from the degree of dilution. The gas of specific gravity 0·6 was produced in a similar way by further diluting the residue remaining after the tests with gas of specific gravity 0·5. Air added in this way is not included in the air-gas ratios given in the tables. These refer solely to the volume of air entrained per c.ft. of injecting medium.

When the tests were completed, it was felt that it would be a matter of interest, both theoretical and practical, to carry out tests with gas of still higher specific gravity, and particularly to investigate the case when the injecting gas was of approximately the same density as the air injected. These data also give greater confidence in the results over a wide range, than mere extrapolation of the curves already obtained. A heavy gas for experiments with the short-shank burner was produced by filling the experimental holder with a mixture of flue gas and air. Some attempt was made to reduce the specific gravity to 1·0 by adding a small amount of coal gas. The subsequent absorption of CO_2 on standing left the residue with a slightly lower specific gravity than was intended, but this in no way vitiates the data.

In order that our results should not be entirely dependent upon the peculiarities of one piece of apparatus, the whole series of tests was repeated with a second burner, using, however, the same gas jet as in the first series of tests. This burner is illustrated by fig. 1, and its principal dimensions are indicated in Table 1. Similar gas mixtures were used except in the case of the heavy gas. It was found that a higher CO_2 content of the injecting gas would materially improve the accuracy and ease of testing, and so the holder was filled with air mixed with a suitable amount of CO_2 from a cylinder. Due allowance is made for the fact that the specific gravity is well above 1·0, in drawing conclusions from the data.

The results of the tests are given in Tables 1 to 6 and

TABLE 1. (See also fig. 1.)

PRINCIPAL DATA REGARDING BURNERS USED FOR TESTS.

Gas Jet Used with both Burners.

Cross-section as shown in fig. 2. Diameter at outlet = 0·0890 in. Area of cross-section 0·00622 sq. in. Corresponds with No. 43 Morse drill. The tip of the jet was in all cases just outside the end of the mixing tube.

Mixture Outlets.

30 drilled holes each 0·1405 in. diameter = 0 01550 sq. in. area. Corresponds with No. 28 Morse drill. Total outlet area 0·465 sq. in. in each case.

	Long Shank Burner.	Short Shank Burner.
Overall diameter of burner head .	3 in.	4 in.
Length of mixing tube to junction with ring	13⅛ in. (including elbow	4 in.
Bore of mixing tube (approximately)	⅝ in.	⅝ in.
Approximate distance between centres of outlets—		
Inner circle of 11 holes . . .	0·40 in.	0·64 in.
Outer circle of 19 holes . . .	0·38 in.	0·45 in.

* Phil. Mag., Ser. 6, Vol. 44, Nov. 1922, pp. 969-988.
,, ,, ,, 46, ,, 1923, ,, 785-801.
† See "JOURNAL," July 4, 1923, p. 104.

TABLE 2.—(*See also fig.* 2.) *Tests with Short-Shank Burner, Cold, Using Gases of Different Specific Gravities.* (*Results Given on Equal Pressure Basis.*)

Sp. Gr. of Gas	0·408				0·509				0·606				0·982			
Gas Analysis Number	1				2				3				4			
Pressure at Jet. Inches Water Gauge.	Uncorrected Gas Rate. C.Ft. per Hour.	Air/Gas Ratio.	P.Ct. of Injection at 3 in. Pressure.	C.Ft. Air Injected per Hour.	Uncorrected Gas Rate. C.Ft. per Hour.	Air/Gas Ratio.	P.Ct. of Injection at 3 in. Pressure.	C.Ft. Air Injected per Hour.	Uncorrected Gas Rate. C.Ft. per Hour.	Air/Gas Ratio.	P.Ct. of Injection at 3 in. Pressure.	C.Ft. Air Injected per Hour.	Uncorrected Gas Rate. C.Ft. per Hour.	Air/Gas Ratio.	P.Ct. of Injection at 3 in. Pressure.	C.Ft. Air Injected per Hour.
0·25	6·41	2·60	84	16·7	5·68	2·77	82	15·7	5·27	2·86	79	15·1	4·29	3·06	68	13·1
0·50	9·48	2·80	90	26·5	8·51	3·08	92	26·2	7·87	3·38	94	26·6	6·21	3·92	87	24·4
1·00	13·65	2·92	94	39·9	12·4	3·22	96	40·0	11·3	3·50	97	39·6	9·06	4·45	99	40·3
2·00	19·6	3·01	97	59·0	17·9	3·30	98	59·1	16·3	3·55	99	57·9	13·1	4·50	100	59·0
3·00	24·4	3·09	100	75·7	22·2	3·36	100	74·6	20·2	3·60	100	72·7	16·2	4·51	100	75·0
Average tabular number during tests	1·020				1·017				1·026				1·019			

TABLE 3.—(*See also fig.* 3.) *Tests with Short-Shank Burner, Cold, Using Gases of Different Specific Gravities.* (*Same Data as in Table 2, presented on Equal Gas Rate Basis.*)

Sp. Gr. of Gas	0·408				0·509				0·606				0·982			
Gas Analysis Number	1				2				3				4			
Uncorrected Gas Rate. C.Ft. per Hour.	Pressure at Jet. Inches Water Gauge.	Air/Gas Ratio.	P.Ct. of Injection at 25 C.Ft. per Hour.	C.Ft. Air Injected per Hour.	Pressure at Jet. Inches Water Gauge.	Air/Gas Ratio.	P.Ct. of Injection at 25 C.Ft. per Hour.	C.Ft. Air Injected per Hour.	Pressure at Jet. Inches Water Gauge.	Air/Gas Ratio.	P.Ct. of Injection at 25 C.Ft. per Hour.	C.Ft. Air Injected per Hour.	Pressure at Jet. Inches Water Gauge.	Air/Gas Ratio.	P.Ct. of Injection at 25 C.Ft. per Hour.	C.Ft. Air Injected per Hour.
6·0	0·22	2·53	82	15·2	0·27	2·82	83	16·9	0·31	3·10	85	18·6	0·46	3·85	84	23·1
8·0	0·37	2·73	89	21·8	0·45	3·05	90	24·4	0·52	3·38	93	27·1	0·80	4·40	96	35·2
10·0	0·55	2·81	91	28·1	0·67	3·15	93	31·5	0·79	3·45	95	34·5	1·21	4·49	98	44·9
15·0	1·20	2·95	96	44·3	1·44	3·26	96	48·9	1·70	3·54	97	53·1	2·59	4·51	99	67·6
20·0	2·06	3·02	98	60·4	2·47	3·34	98	66·8	2·94	3·60	99	72·0	4·45	4·52	99	90·4
25·0	3·12	3·09	100	77·0	3·72	3·40	100	85·0	4·47	3·65	100	91·2	..	..	..	..
Average tabular number during tests	1·020				1·017				1·026				1·019			

TABLE 4.—*Particulars of Gases used in Aeration Tests.*

—	Short Burner.				Long Burner.				Gas Fire.	
Analysis No.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Composition CO_2	0·4	0·3	0·3	5·5	0·1	0·1	0·1	15·3	4·7	4·2
C_mH_n	4·2	3·5	2·8	0·4	5·1	4·4	3·5	..	2·1	2·1
O_2	0·1	3·6	7·1	9·5	0·0	2·8	6·4	17 8	2·3	1·0
CO	11·7	9·7	7·8	1·9	10·9	9·4	7·6	..	12·7	12·9
H_2	48·9	40·7	32·5	2·7	45·5	39·3	31·5	..	42·9	46·9
CH_4	31·9	26·5	21·2	2·5	35·0	30·2	24·2	..	20·0	21·6
N_2	2 8	15·7	28·3	77·5	3·4	13·8	26·7	66·9	15·3	11 3
	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100 0	100·0	100 0
Sp. Gr. $\frac{\text{moist gas at 60° F. and 30 in. bar.}}{\text{moist air at 60° F. and 30 in. bar.}}$	0·408	0·509	0·606	0·982	0·424	0·502	0·602	1·080	0·537	0·490
Calculated calorific value B.Th.U. gross per c.ft.	622	..	..	..	663	..	..	..	432	461
C.ft. of air required per c.ft. gas for complete combustion	5·4	..	..	..	5·8	..	..	..	3·6	3·9

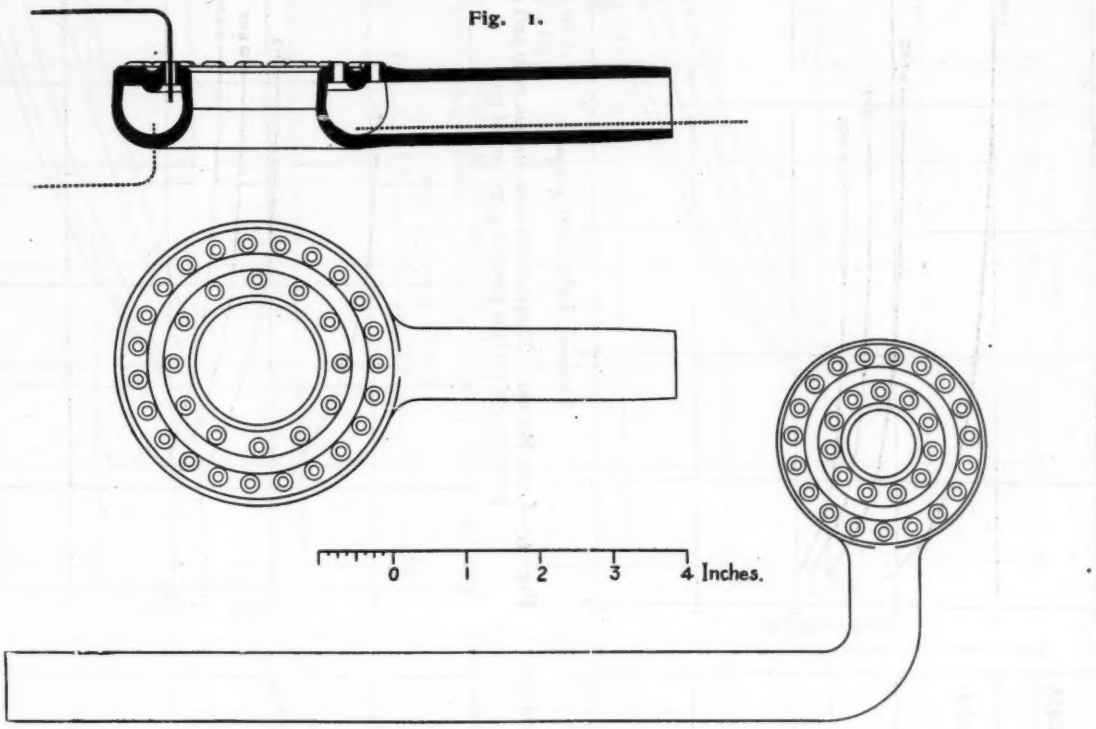
figs. 2 to 9. The curves were plotted on a suitable scale from the original experimental data and, for convenience in presenting and discussing the results, the data given in the tables have been read from the curves to correspond with selected gas rates or pressures.

In considering the results, it must be made quite clear that they apply to burners regarded as being without any means of adjustment, *i.e.*, with a simple nipple orifice of fixed dimensions, fixed air opening, and fixed burner outlets for all tests. During the tests, care was taken that the gas and air temperatures were as nearly alike as possible. The air-gas ratios calculated from these data therefore remain the same, whether the gas and air rates are reduced to standard conditions of temperature and pressure or not. It is probable that substantially the same air-gas ratios would have been obtained if the tests could all have been made at 60° F. and 30 in. barometer, and some evidence on this point is furnished by Thomas for the case in which both the injecting gas and the air were equally heated to temperatures as high as 184° C. (Phil. Mag., Series 6, Vol. 46, Nov. 1923, pp. 785-801.) The effect of deviations from 60° F. and 30 in. barometer upon the relations between pressure, specific gravity of gas, and the discharge through the gas nipple are discussed in Appendix II. The uncorrected gas rates were used in plotting the data.

The curves for the relation between air-gas ratio and either pressure or gas rate for any one kind of gas showed the same characteristics as were noted for these burners in the Ninth Report (p. 209), namely, a rapid increase in air-gas ratio with pressure at low pressures, and above 1 in. pressure a relatively small further increase in air-gas ratio as the pressure was increased up to the limit of our tests—about 3½ in. water gauge. In the case of the short shank burner, the further increase in aeration above 1 in. pressure

Burners Used for Aeration Tests.

Fig. 1.



was not more than 5 p.ct., yielding a very uniform degree of aeration over the working range of the burner. In the case of the long-shank burner, the increase above 1 in. pressure was between 6 and 10 p.ct. This difference in the slope of the aeration curves with the two burners over this range was observable in fig. 10 of the Ninth Report.

Paying attention to the short burner only, as regards relations at constant gas pressure (fig. 2), it will be noted that for gases of different specific gravities the curves preserve the same general character throughout. If they are examined closely, however, it will be found that they are not strictly similar, and above 1 in. pressure there is a distinct tendency for the slope of the curves to diminish as the specific gravity of the injecting gas increases. For the range of specific gravities 0·4 to 0·6, and excluding pressures below ½-in. water gauge, similarity might be assumed for practical purposes.

The long-shank burner exhibits a closer similarity of the aeration curves, on a pressure basis, for gases of different specific gravities. This approximate similarity of the aeration curves for any one piece of apparatus working with gases of different specific gravities at the same pressure was also exhibited in the tube experiments of the Ninth Report (see Table 4, p. 193), and in an apparatus used by Dr. Thomas (Phil. Mag., Series 6, Vol. 46, Nov. 1923, pp. 785-801). Where strict similarity prevails, the work of examining a burner is greatly reduced and the behaviour of the burner can be expressed very concisely. It suffices, for example, to make determinations of the air-gas ratios for a series of pressures with any one grade of gas, and to examine also the behaviour with several gases at one pressure, to be able to state the probable behaviour of the burner over a wide range of conditions. It is clear, however, that in practice strict similarity of the curves for gases of different specific gravities cannot be assumed.

The relations between the degree of aeration and the specific gravity of the injecting gas, when the burner is operated at a constant pressure, are shown by the curves of fig. 6 for the short burner and fig. 8 for the long burner. It is quite plain from these curves that while the air-gas ratio increases as the specific gravity increases, the air-gas ratio is not simply proportional to the specific gravity of the gas.

Turning either to Table 2 or Table 5, it will be observed that for a particular burner approximately the same volume of air was injected per hour for a given jet pressure, whatever the specific gravity of the gas used. This was also found to be the case in some of the tube experiments of the Ninth Report (Medium-Sized Tube experiments, Table 4), and a note on the point appears in the Summary of the Ninth Report (Item 4, also reprinted as a footnote to Summary of the present report). In view of the fact that this relation was not strictly maintained with the large and small tubes, it was plain that a generalization applying to a wide range of conditions could not be put forward. The same caution is necessary here.

Since the quantity of air injected in these experiments was nearly constant at a given pressure, and the gas rate at a given pressure was approximately inversely proportional to the square root of the specific gravity of the gas being used, it follows that the air-gas ratio was approximately proportional to the square root of the specific gravity of the injecting gas, so long as the same pressure was used throughout. Irregularities were, however, exhibited at pressures below ½ in. water gauge. If attention is confined to the range of specific gravities 0·4 to 0·6, which more than covers the range of specific gravity variations normally encountered in town-gas practice, a simpler, but equally serviceable, relation can be substituted, namely, that at the same pressures, the percentage variation in air-gas ratio was one-half the percentage variation in specific gravity. Thus, for an increase of 10 p.ct. in specific gravity, *e.g.*, from 0·48 to 0·53, the air-gas ratio would increase by 5 p.ct., *i.e.*, from (say) 3·00 to 3·15.

Ordinarily the relation between air-gas ratio and specific gravity would be expected to differ according as comparisons were made on a basis of equal gas rates or equal gas pressures. As, however, the aeration curves above ½-in. pressure (and the corresponding gas rates) were almost horizontal for these experiments, it follows that the air-gas ratio was also approximately proportional to the square root of the specific gravity of the gas when comparisons were made at equal gas rates.

In comparing the results yielded by these two burners with corresponding data published in the Ninth Report, certain difficulties arise. It will be observed that the average difference in the degree of aeration attained by the two burners in these tests under similar conditions of use as to specific gravity of gas, gas rate and pressure was about 22 p.ct., whereas in the Ninth Report the difference was about 40 p.ct. During some supplementary experiments performed between the tests with the short and the long burners, the gas nipple was slightly damaged, but not sufficiently to cause its rejection. Close examination of the experimental data reveals the fact that in the second series of tests of the present report the discharge of gas of any given specific gravity has been increased by about 2 p.ct. as compared with the first series, and the relation between

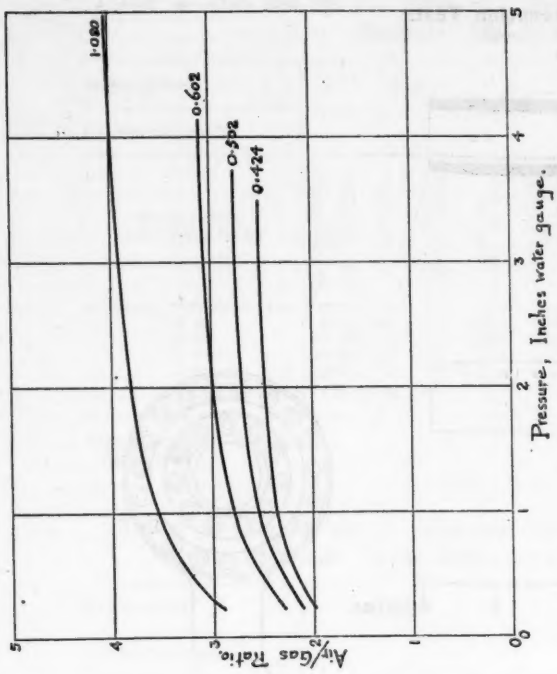


Fig. 4.—Long Burner. Relation between air-gas ratio and gas pressure for various specific gravities of gas.

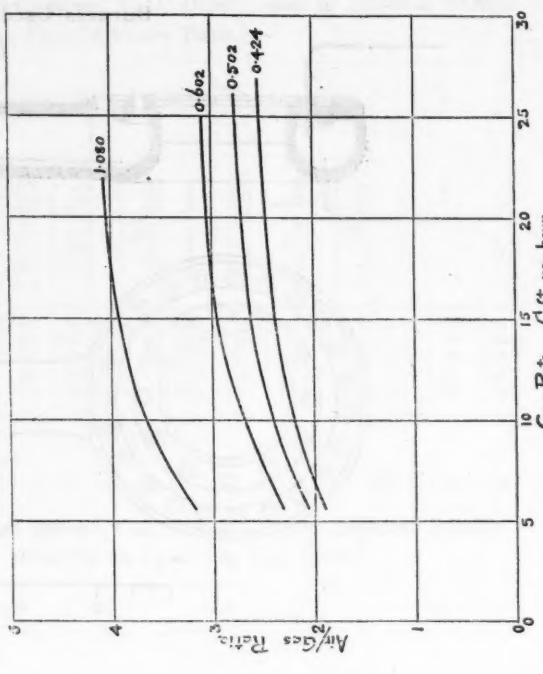


Fig. 5.—Long Burner. Relation between air-gas ratio and gas rate for various specific gravities of gas.

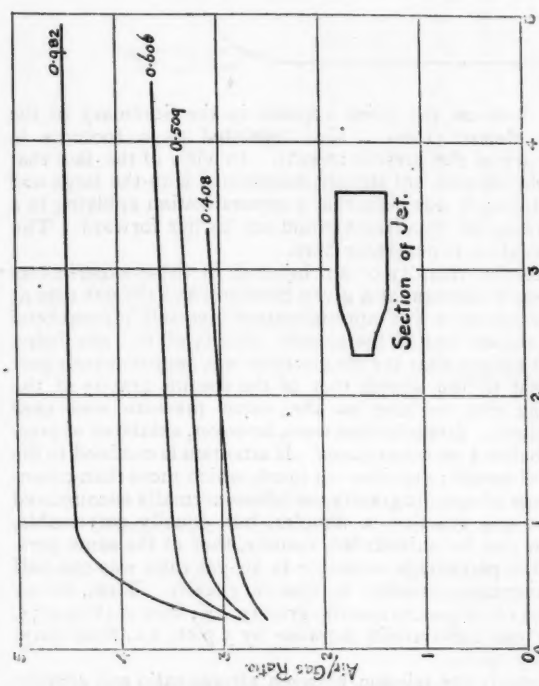


Fig. 2.—Short Burner. Relation between air-gas ratio and gas pressure for various specific gravities of gas.

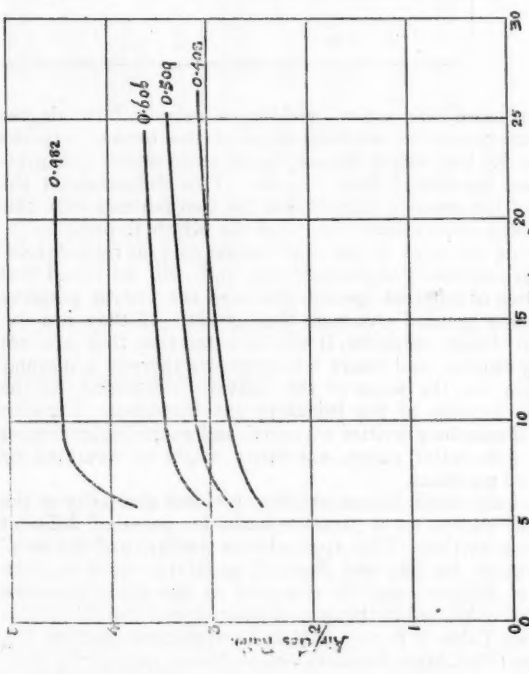


Fig. 3.—Short Burner. Relation between air-gas ratio and gas rate for various specific gravities of gas.

pressure and gas rate has been modified slightly (see Appendix II.*). It is doubtful whether in making a new jet the shape and dimensions of the original nipple could have been reproduced with sufficient accuracy to give better agreement than this, and the influence upon aeration is probably slight. The injury is mentioned here, however, because there are apparent inconsistencies in discharge and pressure data in the two sets of experiments which are outside the assumed limits of experimental error, and not eliminated even when due allowance is made for changes in "tabular number."

It is found, moreover, that the degree of aeration is influenced to a very marked extent by the accuracy with which the jet is centred with respect to the entrance to the air-intake, a matter which requires very close attention in assembling burners if the best results are to be obtained. It would appear that in the tests with the long burner the centering was somewhat better than in the Ninth Report, and the aeration has been increased by about 5 p.ct. in these tests. On the other hand, the setting of the jet with the short burner has resulted in a reduction of about 15 p.ct. in the aeration as compared with the Ninth Report. In neither case did simple inspection reveal any obvious error in the centering of the jet.

However, in view of the fact that each series of tests was conducted without disturbing the apparatus in any way, the tests with the individual burners enable reliable comparisons to be made as regards the influence of specific gravity and pressure changes for each burner. Discrepancies of the kind mentioned may be expected in comparisons of different burners, or of the same burner upon different occasions, and where small differences are being investigated it is essential that no part of the apparatus should be disturbed between tests. It has since been possible, by repeated trials and resetting of the gas nipple, to reproduce the higher air-gas ratios of the Ninth Report with the short burner and gas of specific gravity 0·48, thereby confirming the marked influence of slight differences in the placing of the jet.

Effects upon Aeration when Burners are Lighted.

In gas-burners, the air-gas mixture formed by an injector usually becomes heated during its passage through the burner body, and, for a given volume of cold gas and air en-

* This Appendix is not yet complete, and will be published at a later date.

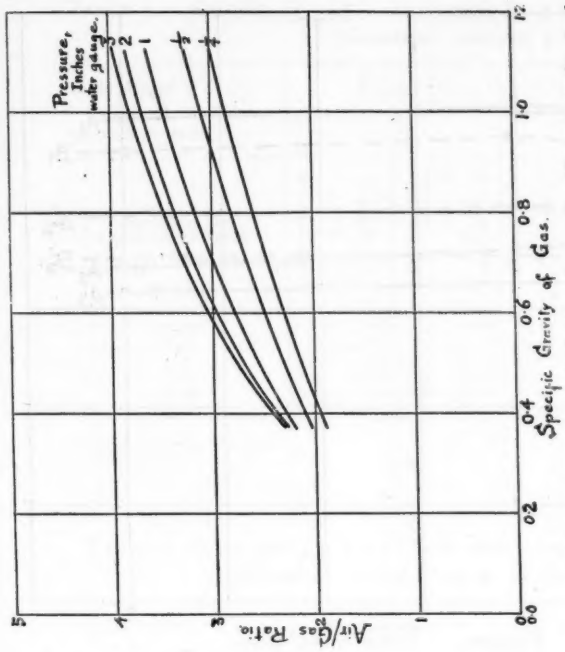


Fig. 8.—Long Burner. Relation between air-gas ratio and specific gravity at various gas pressures.

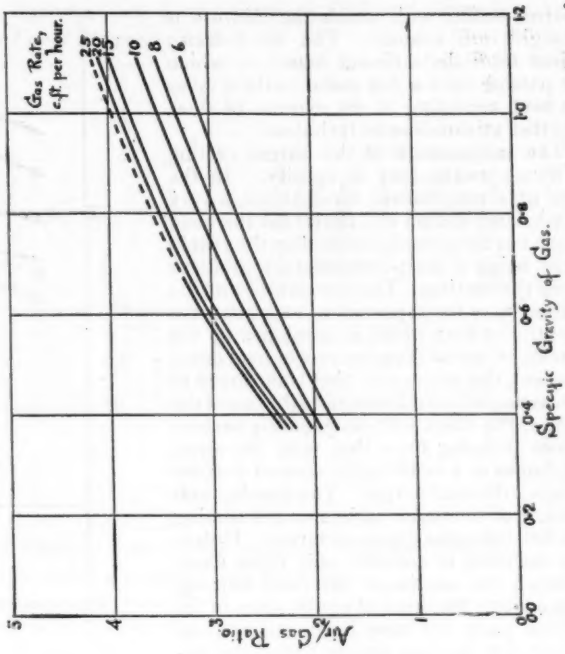


Fig. 9.—Long Burner. Relation between air-gas ratio and specific gravity at various gas rates.

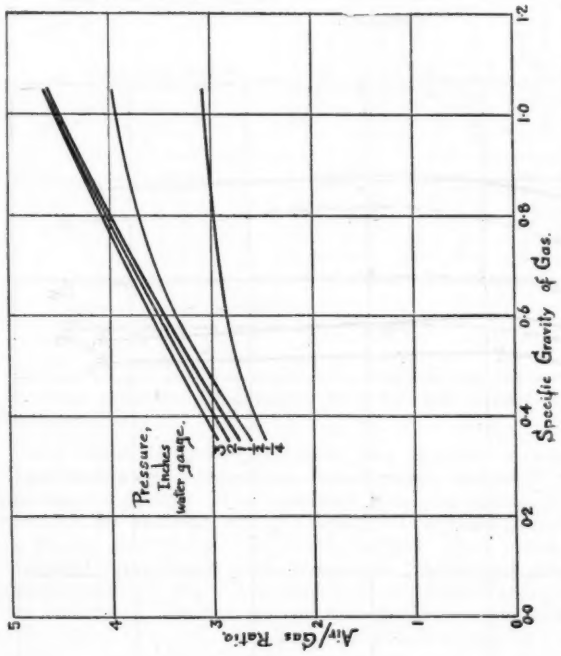


Fig. 6.—Short Burner. Relation between air-gas ratio and specific gravity at various gas pressures.

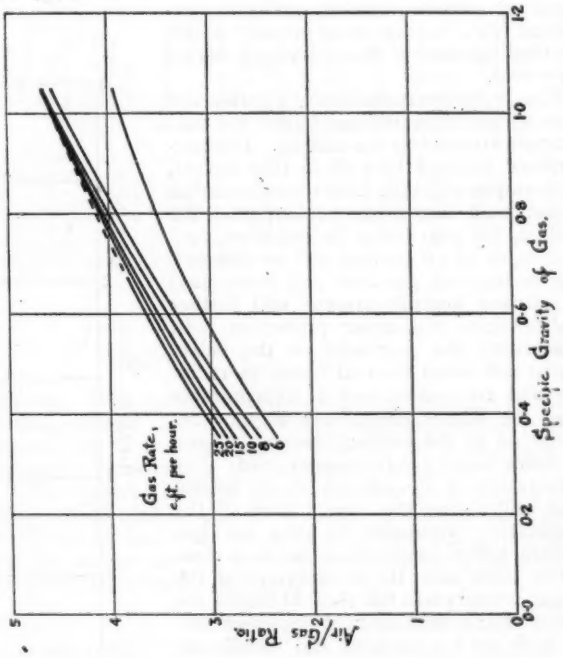


Fig. 7.—Short Burner. Relation between air-gas ratio an specific gravity at various gas rates.

tering the burner, a larger volume must be expelled through the burner outlets according to the temperature the mixture has attained on reaching that point. It is true that this heating simultaneously reduces the density of the mixture, but the net result is, that for the expulsion of a given quantity of mixture through the burner openings, a higher pressure must be developed at the burner outlets than when the mixture remains cold. This has been confirmed experimentally by Dr. Thomas (Phil. Mag. Series 6, Vol. 46, Nov., 1923, p. 789).

In certain cases putting the burner into use will bring into operation convective forces which will provide the necessary additional pressure difference to maintain, or even augment, the quantity of mixture passing; but in others, notably the ordinary types of ring burner, this additional pressure difference is not forthcoming, and the quantity of mixture expelled may be expected to diminish. It has been found that the gas rate at the jet is not measurably affected by small pressure changes in the burner itself, so that in the latter case the whole of the reduction is borne by the air entrained, and the air-gas ratio would be expected to fall in consequence. The question of the extent of heating of the mixture in its passage through the burner and the effect upon the degree of aeration is therefore one requiring some consideration.

The factors which might be expected to have the greatest influence in this connection are the temperature of the burner casting, the time during which the mixture is in contact with it, and the nature of the contact. The time factor

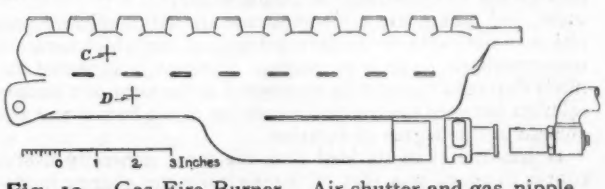


Fig. 10.—Gas Fire Burner. Air shutter and gas nipple drawn back to indicate construction.

can be conveniently sub-divided into two parts, one being the rate in cubic feet per hour at which the mixture is passed through the appliance, and the other being dependent upon the design of the burner, particularly as regards the length and cross-sectional area of its passages (governing the linear velocity of the mixture in the burner) and the extent of

heated surface with which the mixture is brought into contact. The third factor arises from the different extent to which air passing over a hot metal surface takes up heat according to its manner of flow, whether stream-line or turbulent.

The temperature of the burner casting is by no means easy to specify. In the case of a ring burner, for example, a very rough examination will show that the head of the burner is much hotter than the shank, there being a steep temperature gradient along the casting. The temperature of the casting may be expected to vary with the quantity of heat which is developed by the burner. Even at the same rate of heat development, the amount of heat transferred to the casting will be influenced by the size of the flames; the effect with long, poorly aerated flames differing from that with the short hot flames of a more highly aerated mixture of equal thermal output. The number and spacing of the flame outlets on the casting also will influence its temperature. Unless it is desirable to consider only those cases in which the appliance has been burning long enough for thermal equilibrium of its various parts to have been attained, its weight and the time during which the appliance has been in operation will be factors requiring consideration, especially in operations (*e.g.*, boiling tests) of only a few minutes' duration, if the appliance is started from cold.

Finally, the surroundings of a burner will have an important influence upon the temperature attained by the casting. The temperature attained by a plain ring burner, for example, will differ from that of a similar burner built into a gas cooker, since the facilities for heat losses by radiation, conduction, or by air cooling, will be different. The burners of gas-fires and those used for furnace heating present still further modifications of burner protection. In most cases the proximity of the vessel heated will affect thermal losses by radiation and air-cooling, and in unfavourable cases the flames themselves may be deflected on to the casting, thereby causing excessive heating of the burner head. The temperature of the casting at its hottest point will define the upper limit of the temperature attainable by the air-gas mixture before combustion, but it is clear that in most cases the temperature of the air-gas mixture will fall short of that of the casting chiefly on account of imperfect contact with the hot surfaces and insufficient time-contact.

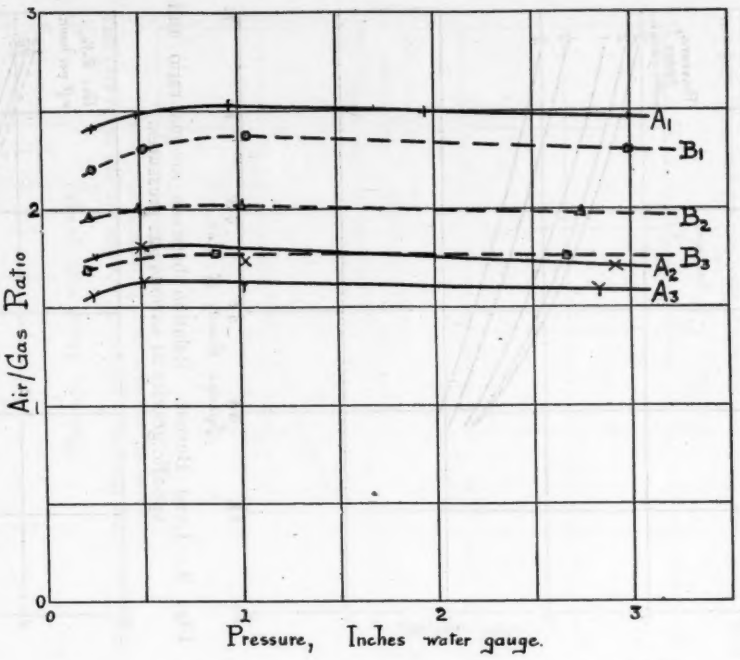


Fig. 11.—Gas Fire. Relation between air-gas ratio and gas pressure.

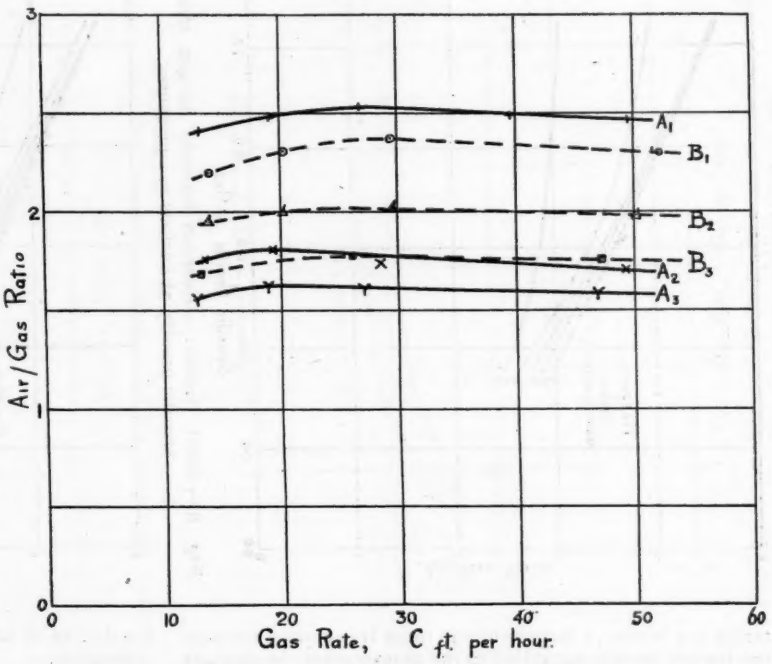


Fig. 12.—Gas Fire. Relation between air-gas ratio and gas rate.

Experiments with Hot Burners.

The foregoing outline of the altered conditions brought into operation when a burner is lighted will serve to indicate the complexity of the problem. Some of the factors are not controllable during experiment, and others are difficult to specify with sufficient precision to indicate exactly the conditions under which aeration measurements have been made. Further, it appeared unlikely that results could be expressed in the form of a simple relation between the thermal condition of the burner and the change in the degree of aeration.

It was therefore decided that the most generally useful course to adopt was that of determining the change in degree of aeration produced on allowing our ring burners to operate under ordinary working conditions, comparisons being made with the degree of aeration of the burner working under similar conditions as regards gas quality, rate, and pressure, but with the gas unlighted. Actually, the tests here quoted were interspersed at convenient points among the tests of Tables 2—6, in order to avoid the necessity for duplicating tests with the burners cold. Exactly the same methods of testing were used as for the cold burner, but the aeration measurements for the hot burner were not made until the burner had been in operation with the gas burning at a steady rate for at least half-an-hour.

The results obtained may be regarded as typical for this class of burner, but obviously the precise value of the change may be expected to fluctuate somewhat according to the dimensions of the burner and the conditions of use.

Short Shank Burner.—The burner was operated with gas of specific gravity 0·408 at 3 in. pressure—*i.e.*, with a gas rate of about 24·5 c.ft. per hour. The inner cones of the flames were well marked. Gas corresponding with analysis No. 1, Table 4, was used. The tests were repeated on four occasions with the following reduction in aeration as compared with the result given in Table 2 for this gas at 3-in. pressure with the cold burner.

(i.) 10·6 p.ct. (ii.) 10·9 p.ct. (iii.) 9·7. p.ct. (iv.) 9·3 p.ct.

TABLE 5.—(*See also fig.* 4.) *Tests with Long Shank Burner, Cold, Using Gases of Different Specific Gravities.* (*Results given on Equal Pressure Basis.*)

Sp. Gr. of Gas	0·424				0·502				0·602				1·080			
Gas Analysis Number	5				6				7				8			
Pressure at Jet. Inches Water Gauge.	Uncorrected Gas Rate. C.Ft. per Hour.	Air/Gas Ratio.	P.Ct. of Injection at 3 in. Pressure.	C.Ft. Air Injected per Hour.	Uncorrected Gas Rate C Ft. per Hour.	Air/Gas Ratio.	P.Ct. of Injection at 3 in. Pressure.	C.Ft. Air Injected per Hour.	Uncorrected Gas Rate. C.Ft. per Hour.	Air/Gas Ratio	P.Ct. of Injection at 3 in. Pressure.	C.Ft. Air Injected per Hour.	Uncorrected Gas Rate. C.Ft. per Hour.	Air/Gas Ratio.	P.Ct. of Injection at 3 in. Pressure.	C.Ft. Air Injected per Hour.
0·25	6·58	2·00	79	13·2	6·04	2·13	77	12·9	5 64	2·31	75	13·0	4 28	2 95	75	12 6
0·50	9·57	2·16	86	20 7	8·87	2 30	84	20 4	8·22	2·51	82	20·6	6 15	3 20	82	19 7
1·00	13 8	2·36	94	32·6	12 7	2·55	93	32·4	11 8	2·80	91	33 0	8 85	3 58	91	31·6
2 00	19·9	2·46	98	49·0	18·2	2·70	98	49·1	17 1	3 00	98	51·3	12 6	3·80	97	47 9
3 00	24·5	2 52	100	61·8	22·5	2 75	100	61·9	21 2	3·07	100	65 1	15·6	3·92	100	61·1
Average tabular number during tests	1·004				0·994				0·983				1·006			

TABLE 6.—(*See also fig.* 5.) *Tests with Long-Shank Burner, Cold, Using Gases of Different Specific Gravities.* (*Same Data as in Table 5, presented on Equal Gas-Rate Basis.*)

Sp. Gr. of Gas	0·424				0·502				0·602				1·080			
Gas Analysis Number	5				6				7				8			
Uncorrected Gas Rate. C.Ft. per Hour.	Pressure at Jet. Inches Water Gauge.	Air/Gas Ratio.	P.Ct. of Injection at 25 C.Ft. per Hour.	C.Ft. Air Injected per Hour.	Pressure at Jet. Inches Water Gauge.	Air/Gas Ratio.	P.Ct. of Injection at 25 C.Ft. per Hour.	C.Ft. Air Injected per Hour.	Pressure at Jet. Inches Water Gauge.	Air/Gas Ratio.	P.Ct. of Injection at 25 C.Ft. per Hour.	C.Ft. Air Injected per Hour.	Pressure at Jet. Inches Water Gauge.	Air/Gas Ratio.	P.Ct. of Injection at 25 C.Ft. per Hour.	C.Ft. Air Injected per Hour.
6·0	0·21	1·92	76	11·5	0 24	2·10	76	12·6	0·28	2 35	76	14·1	0·47	3·24	78	19·4
8·0	0 36	2·09	83	16·7	0·41	2·27	82	18·2	0·48	2·52	81	20·2	0·83	3·49	84	27·9
10·0	0·54	2·19	87	21·9	0·63	2·40	87	24 0	0·72	2·69	87	26·9	1·27	3·66	89	36 6
15·0	1·17	2·38	94	35 7	1·36	2·62	95	39·3	1·55	2·96	95	44 4	2·76	3 93	95	59·0
20·0	2·04	2·46	98	49 2	2·38	2·70	98	54·0	2 69	3·05	98	61·0	4·82	4·05	98	81·0
25·0	3·10	2·52	100	63·0	3·62	2·76	100	69·0	4·07	3 10	100	77·5	..	..	..	..
Average tabular number during tests	1·004				0·994				0·983				1·006			

the mean reduction of aeration with the hot burner was therefore 10·1 p.ct.

Long Shank Burner.—This burner was operated with gas of specific gravity 0·424 at 2-in. water gauge, or 20 c.ft. per hour approximately. The gas used was of a composition indicated by analysis No. 5, Table 4. The inner cones of the flames were visible but poorly defined. The result is compared with that at 2-in. pressure in Table 5 for gas of specific gravity 0·424. A reduction in aeration of 16·2 p.ct. was observed. Similar tests at 3-in. pressure indicated a reduction of 14·6 p.ct. The mean is therefore slightly over 15 p.ct. A test carried out at 3-in. pressure only 10 minutes after lighting the burner showed a smaller reduction, viz., 12·4 p.ct. It was clear that, although thermal equilibrium had not been established, the reduction in aeration was very marked even in this short time.

It will be noted that the percentage reduction in aeration with the long burner was greater than with the short burner. By placing small fragments of solder on various points of the castings and observing their behaviour, it was inferred that the head of the long burner attained a temperature above 200° C., while that of the short burner was below this temperature. The result of the aeration tests, therefore, is quite in accordance with that to be expected from the higher temperature of the long casting and the more favourable opportunities it offered for heating up the air-gas mixture. Pressure measurements were also made on the castings immediately below the burner outlets. From these data it is possible to make a rough estimate of the temperature attained by the air-gas mixture (*see* Appendix II.). These values for typical operating conditions were:

For the short burner . . . . . 118° C. ± 15° C.
" " long " . . . . . 240° C. ± 30° C.

An interesting experiment was conducted several times with each burner. It consisted in determining the aeration of the burner cold, and again *as soon as possible after lighting*. The results indicated either no change, or a very trifling change (2 to 3 p.ct.) which could be ascribed to the heating up of the castings in the two or three minutes necessary for collecting the samples for analysis.

This means that the flames and hot gases above the burner head play no part in the aeration mechanism of ring burners, and that the modified aeration results observed with the hot burners are due entirely to heating up of the air-gas mixture in the burner castings.

PRESSURES IN BURNER BODIES.

It was thought that useful information might possibly be obtained by studying the relation between the pressure operating the gas jet and that developed in the burner head, as suggested by J. G. Clarke ("JOURNAL," March 14 and 21, 1923). The pressures developed in the annular chamber constituting the head of a ring burner are very small, and typical figures are usually under 0·05 in. water gauge, *e.g.*, for the short ring burner of our tests supplied with gas of specific gravity 0·5 at a jet pressure of 3 in. water gauge, the pressure immediately below the burner outlet was found to be only 0·026 in. water gauge.

There does not appear to be any very simple relation between the pressure developed in the burner head and the pressure operating the gas jet in the cases we have examined. For equal jet pressures, the pressure developed in the head of the short burner was practically independent of the specific gravity of the injecting gas, but in the case of the long burner there was a tendency for a slight increase in burner pressure with increase in specific gravity of the injecting gas.

The chief value of such measurements is perhaps in the direction of indicating the amount of obstruction offered to the final outflow of the air-gas mixture, and in improving the design of such outlets. A high pressure developed in a burner body of itself means little, as it may be due to a restricted outlet, to a high air-gas ratio, or to a high air-gas

TABLE 7.—*Aeration Tests with Gas-Fire—Presented on Pressure Basis.* (*See also fig.* 11.)

Gas Used.	Composition as Analysis No. 9, Table 4—Sp. Gr. 0·537.											
Conditions of Test.	Burner Cold. Air Shutter Fully Open, *i.e.*, Slot $\frac{5}{16}$ ins. Wide.				Burner Cold. Air Shutter Partly Closed Leaving Slot $\frac{7}{64}$ ins. Wide.				Burner Hot. Air Shutter Partly Closed Leaving Slot $\frac{7}{64}$ ins. Wide.			
Relevant Curve in Fig. 11.	A_1.				A_2.				A_3.			
Column No. 1.	2	3	4	5	6	7	8	9	10	11	12	13
Pressure at Jet Inches Water Gauge.	Uncorrected Gas Rate C.Ft. per Hr.	Air/Gas Ratio	P.Ct. of Injection at 3 in. Pressure	C Ft. Air Injected per Hr.	Uncorrected Gas Rate C.Ft. per Hr.	Air/Gas Ratio	P.Ct. of Injection at 3 in. Pressure.	C.Ft Air Injected per Hr.	Uncorrected Gas Rate C.Ft. per Hr.	Air/Gas Ratio.	P.Ct. of Injection at 3 in. Pressure.	C.Ft. Air Injected per Hr.
0·25	13·3	2·41	98	32·0	13·3	1·75	103	23·3	12·9	1·56	99	20·1
0·50	19·2	2·49	101	47·8	19·2	1·81	106	34·8	18·6	1·63	103	30·3
1·00	27·6	2·53	103	69·8	27·6	1·80	106	49·7	26·8	1·62	103	43·4
2·00	40·0	2·50	102	100·0	40·0	1·74	102	69·6	38·8	1·60	101	62·1
3·00	49·6	2·46	100	122·0	49·6	1·70	100	84·4	47·9	1·58	100	75·7
Average tabular number	1·034				1·032				1·023			

Gas Used.	Composition as Analysis No. 10, Table 4—Sp. Gr. 0·490.											
Conditions of Test.	Burner Cold. Air Shutter Fully Open, *i.e.*, Slot $\frac{5}{16}$ ins. Wide.				Burner Cold. Air Shutter Partly Closed Leaving Slot $\frac{5}{32}$ ins. Wide.				Burner Hot. Air Shutter Partly Closed Leaving Slot $\frac{5}{32}$ ins. Wide.			
Relevant Curve in Fig. 11.	B_1.				B_2.				B_3.			
Column No. 1.	14	15	16	17	18	19	20	21	22	23	24	25
Pressure at Jet Inches Water Gauge.	Uncorrected Gas Rate C.Ft. per Hr.	Air/Gas Ratio.	P.Ct. of Injection at 3 in. Pressure.	C.Ft. Air Injected per Hr.	Uncorrected Gas Rate C.Ft. per Hr.	Air/Gas Ratio.	P.Ct. of Injection at 3 in. Pressure.	C.Ft. Air Injected per Hr.	Uncorrected Gas Rate C.Ft. per Hr.	Air Gas Ratio.	P.Ct. of Injection at 3 in. Pressure.	C.Ft. Air Injected per Hr.
0·25	13·9	2·20	96	30·7	14·5	1·95	99	28·3	13·8	1·70	97	23·5
0·50	20·1	2·30	100	46·2	20·6	2·00	102	41·2	19·7	1·76	100	34·7
1·00	28·9	2·38	103	68·8	29·3	2·02	103	59·2	28·1	1·77	101	49·7
2·00	41·7	2·34	102	97·6	41·7	2·00	102	83·4	40·1	1·76	100	70·6
3·00	51·6	2·30	100	118·7	51·3	1·97	100	101·0	49 4	1·76	100	87·0
Average tabular number	1·003				1·000				0·994			

mixture rate in a very efficient burner. As explained elsewhere, such pressure measurements have been used for deducing the effective temperature attained by air-gas mixtures in traversing burner castings.

Since the pressures to be measured are so small, very sensitive gauges are necessary, and it seemed that the well-known Chattock tilting manometer would be a suitable instrument for the purpose. Designs for an instrument of this type were prepared, and certain improvements were incorporated, chiefly to facilitate the use of the instrument for technical work. The instrument was constructed for us by the makers of the Fairweather calorimeter, and so far as its mechanical operation is concerned it has proved quite satisfactory. The instrument is illustrated by figs. 13, 14, and 15.

Fig. 13 shows the stationary member of the gauge with levelling feet, longitudinal level, and two fixed pivots at the left-hand end of the frame. The micrometer hand-wheel and tilting pivot are also shown, together with the index for reading. The radial scale for reading whole revolutions of the micrometer head appears on the extreme right. Fig. 14 is a separate view of the slotted plate carrying the microscope, illuminating mirror, and counterpoise.

Fig. 15 shows the instrument as assembled ready for use, with the tilting frame and **U**-tube in position. The upper part of the middle vessel is filled with castor oil, and the remainder of the gauge with a solution of common salt of specific gravity 1·07. The distance between the fixed and moving pivots is 25 cm., and between centres of the **U**-tube limbs, 35 cm. A micrometer screw of 1 mm. pitch is used in this instrument.

The principal improvements in the instrument illustrated are as follows:—

1. Renewable pivots and bearing surfaces.
2. Longitudinal and cross levels for rapidly securing approximate levelling when the instrument is moved from one situation to another.
3. Loose but permanently attached footstep bearings to the levelling feet.
4. Split bush to the tilting-screw for taking up wear.
5. Improved index working on edge of tilting-screw hand-wheel.
6. Slotted counterpoised member which allows considerable latitude of movement to the illuminating and reading device, without altering their relative positions. This movement is necessary in order to view the indicating meniscus under the most favourable conditions.

This type of gauge is employed for determining gas densities, in the manner described in a pamphlet issued by the Fuel Research Board. (Technical Paper No. 5, "An Apparatus for the Measurement of Specific Gravity of Gases in Small Quantities." 1922.) Considerable success has also been attained by the use of a simple type of tilting manometer described by Watson ("Practical Physics," 1913 Ed., pp. 143-4). Xylol is used for filling the gauge, and readings are consistent to about $\frac{1}{1000}$ in. water gauge. In all cases where such small pressure readings are made, frequent zero checks are necessary, draughts must be minimized, flexure of the bench carrying the instrument must be avoided, and the character of the gas filling the connections to the gauge must be carefully considered, or spurious readings due to hydrostatic differences may be obtained.

Aeration Tests with a Gas-Fire.

Similar tests to those carried out with ring burners were next undertaken for a gas-fire. This represents a larger and different type of appliance, and as a 14-in. fire was used, the gas consumption could be taken as high as 50 c.ft. per hour and still be within the working range of the fire. The gas nipple was not capable of adjustment, but consisted of three "fixed" orifices 0·082 in. in diameter, placed on the circumference of a circle of 0·16 in. radius. The nipple itself was drawn back 5-16 in. from the end of the mixing tube. The fire was provided with an air shutter (see fig. 10) which was a sliding fit on the body of the nipple at one end, and rested loosely on the end of the mixing tube at the other. It was adjusted and fixed by a screw running through a lug

TABLE 8.—*Aeration Tests with Gas-Fire—Same Data as in Table 7—Presented on Gas-Rate Basis.*
(See also fig. 12.)

Gas Used.	Composition as Analysis No. 9, Table 4—Sp. Gr. 0·537.											
Conditions of Test.	Burner Cold.				Burner Cold.				Burner Hot.			
	Air Shutter Fully Open, *i.e.*, Slot $\frac{7}{16}$ ins. Wide.				Air Shutter Partly Closed Leaving Slot $\frac{7}{64}$ ins. Wide.							
Relevant Curve in Fig. 12.	A_1.				A_2.				A_3.			
Column No. 1.	2	3	4	5	6	7	8	9	10	11	12	13
Uncorrected Gas Rate C.Ft. per Hr.	Pressure at J-t. Inches Water Gauge.	Air/Gas Ratio.	P.Ct. of Injection at 50 C.Ft. per Hr.		Pressure at Jet Inches Water Gauge.	Air/Gas Ratio.	P Ct. of Injection at 50 C.Ft. per Hr.		Pressure at Jet Inches Water Gauge.	Air/Gas Ratio.	P.Ct. of Injection at 50 C.Ft. per Hr.	
15·0	0·31	2·44	99		0·31	1·78	105		0·33	1 60	101	
20·0	0·54	2·49	101		0·54	1·81	106		0·57	1·63	103	
30·0	1·16	2·52	102		1·16	1·78	105		1 23	1 61	102	
40 0	2·00	2·50	102		2 00	1·74	102		2·13	1·60	101	
50 0	3·06	2 46	100		3·06	1·70	100		3 24	1·58	100	
Average tabular number	1·034				1·032				1·023			

Gas Used.	Composition as Analysis No. 10, Table 4—Sp. Gr. 0·49.											
Conditions of Test.	Burner Cold.				Burner Cold.				Burner Hot.			
	Air Shutter Fully Open, *i.e.*, Slot $\frac{7}{16}$ ins. Wide.				Air Shutter Partly Closed Leaving Slot $\frac{5}{32}$ ins. Wide.							
Relevant Curve in Fig. 12.	B_1.				B_2.				B_3.			
Column No. 1.	14	15	16	7	18	19	20	21	22	23	24	25
Uncorrected Gas Rate C.Ft. per Hr.	Pressure at Jet Inches Water Gauge.	Air/Gas Ratio.	P.Ct. of Inje tion at 50 C.Ft. per Hr.		Pressure at Jet Inches Water Gauge.	Air/Gas Ratio.	P.Ct. of Injection at 50 C.Ft. per Hr.		Pressure at Jet Inches Water Gauge.	Air/Gas Ratio.	P.Ct. of Injection at 50 C.Ft. per Hr.	
15·0	0·29	2 22	97		0·27	1·96	99		0·29	1·71	98	
20·0	0·49	2 30	100		0·47	2·00	101		0·51	1·76	101	
30·0	1·06	2·38	103		1·04	2·02	102		1·13	1·78	102	
40·0	1·84	2·34	102		1·84	2·00	101		2·00	1·76	101	
50 0	2 83	2·30	100		2·86	1·98	100		3·06	1·75	100	
Average tabular number	1·003				1·000				0·994			

(not shown). The casting was somewhat complex, as can be seen from fig. 10. The gas injected into a mixing tube about 6 in. long, tapering from $\frac{3}{4}$ in. to $\frac{5}{8}$ in. in the first 2 in., and which turned at right angles near the centre of the casting delivering into an intermediate mixing chamber. From this the mixture was delivered by nine feeders into a distributing chamber carrying 10 nipples. These were 9-32 in. diameter, and therefore provided a total outlet area of 0·62 sq. in. The firebrick back and radiants of the fire were of ordinary patterns. The fire was connected to an ordinary domestic chimney, and as the laboratory was on a first floor, the available height of flue would be about 28 ft. to the top of the stack. There was no evidence of down-draught. The casting was drilled for a sampling tube and for pressure measurements at points C and D.

The sequence of tests was as follows:—

(1) The air-slide was opened to the utmost extent and air-gas ratios were determined at a succession of selected gas rates and pressures, *the appliance being cold and the gas unlighted*. This was taken as representing the maximum amount of air that the appliance would inject for any particular gas quality and pressure.

(2) The fire was lighted and the air shutter was adjusted to give flames of a suitable character for best all-round operating conditions with the available gas supply. In this case the result aimed at was a silent fire with rather soft flames, having visible, but not well-defined inner cones, but showing no signs of luminosity. After establishing flames of a suitable character the fire was extinguished and when quite cold the tests under (1) were repeated.

(3) The fire was then lighted, starting at about one-quarter to one-third of its normal gas rate, and allowed one hour to attain a steady state. Aeration measurements were made, and then the gas rate was increased, and at the end of a further half hour the test was repeated, and so on until the maximum gas consumption for the fire had been reached.

Throughout these tests the air-shutter retained the setting which had been determined under (2) for the particular gas in use. For each kind of gas an appropriate shutter adjustment was made.

Gas pressures were taken near the nipple with the fire in operation.

The results of the tests are presented in Tables 7 and 8 and in Figs. 11 and 12.

Turning attention first to the tests with the appliance cold, it will be noted that the curves A_1 and B_1 are similar to those obtained with the gas-rings in so far that there is at first a rapid increase in aeration as pressure and gas rate are increased, followed by a state in which the aeration remains almost constant. Unlike the gas-rings, however, the curves for the gas-fire burner show a tendency to *fall* slightly as the pressure and gas rate exceed about 1 in. water gauge or 20-25 c.ft. per hour respectively. The drop is very slight, and might almost have been attributed to experimental irregularities, were it not for the fact that it is exhibited by all six curves in Fig. 11. Curves A_1 and B_1 are similar except at very low gas pressure. The difference in specific gravities of the gases used in the two sets of tests is too small to draw any conclusions as to the relation between air-gas ratio and specific gravity of the injecting gas for this burner.

It will be noted that, even with the air-shutter fully open, the air-gas ratio does not reach a very high value, the highest being about 2·5/1, and the primary aeration therefore corresponding with 64 to 70 p.ct. of the air theoretically necessary for the complete combustion of the gas.

Even this amount of air, however, was greater than it was advisable to supply to the fire, and the air-shutter had to be closed somewhat as indicated in the table, in order to secure the best all-round operating conditions with the gases used for the tests. As the shutter was closed to a different extent

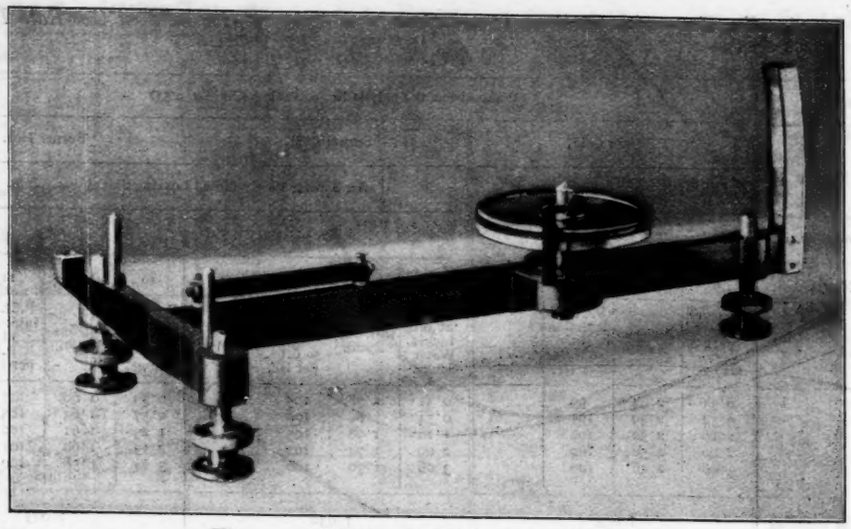


Fig. 13.—Chattock Tilting Manometer.
Levelling Frame.

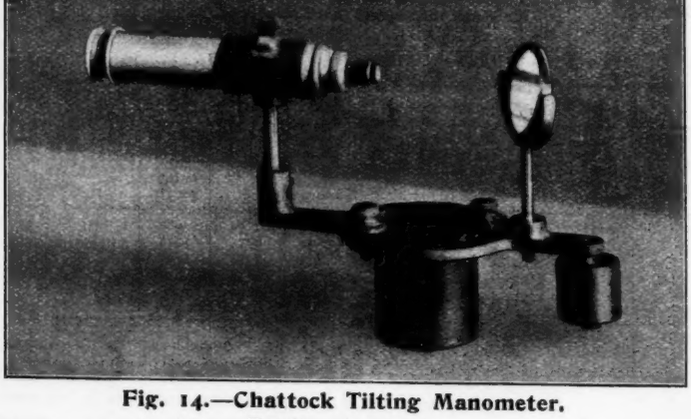


Fig. 14.—Chattock Tilting Manometer.
Reading Apparatus.

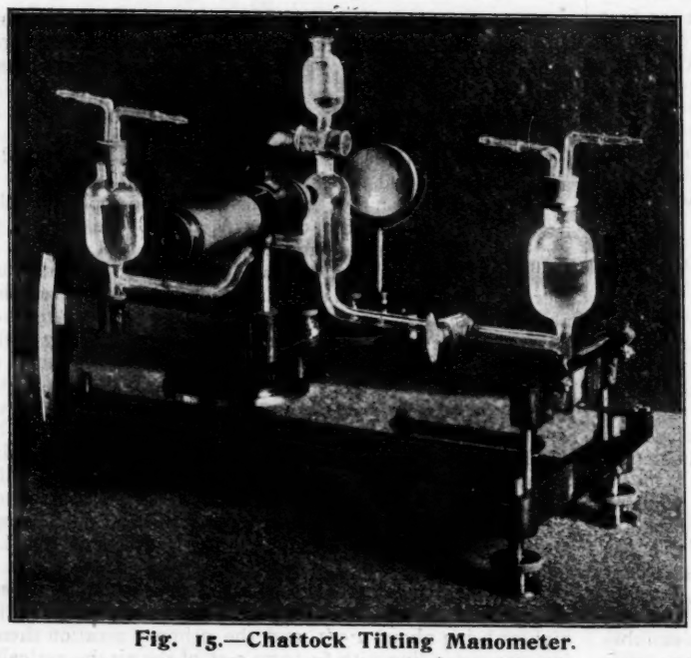


Fig. 15.—Chattock Tilting Manometer.
General View of Complete Instrument.

in the two sets of experiments, the only comparisons which can be fairly made are those between the hot and the cold appliance, using the same gas, *i.e.*, comparisons of curves A_2 with A_3, and B_2^1 with B_3.

These yielded the following values:

TABLE 9.

Gas Pressure. Inches Water Gauge.	A_2/A_3 P.Ct.	B_2/B_3 P.Ct.
0·25	89	87
0·50	90	88
1·00	90	88
2·00	92	88
3·00	93	89
Mean	91	88

It will be seen from these values that the difference in air-gas ratio for the hot and cold appliance is about 10 p.ct., and that it shows a comparatively small variation over the operating range of the fire.

No systematic study has yet been made by us as to the relation between air-gas ratio and air-shutter opening. It is clear, however, that the low aeration value with the shutter fully open is not due to insufficient air opening, for reducing the opening to one-half its former value ($\frac{5}{16}$ in. to $\frac{5}{32}$ in.) has only reduced the aeration by about 20 p.ct.

Judging by experience with the ring burners, a reduction of aeration when the burner was lighted of rather more than 10 p.ct. might have been anticipated. It is probable, however, that the chimney draught generated by lighting the fire acted as a partial corrective and prevented the full reduction in aeration.

Further tests are in progress with a 14-in. gas-fire of recent design, and with gases showing rather greater differences in their specific gravities.

SPECIFIC GRAVITY OF GASES.

In connection with our researches there has, from the outset, been a demand for a rapid technical method of determining the specific gravity of gases with an error not exceeding ± 1 p.ct., and in our most recent work ± 0·25 to ± 0·5 p.ct.

Several forms of effusimeter have been tried within the past seven years, but the general indication is that, while it may in by far the greater number of tests not be in error by more than 1 p.ct., there are occasions when the determination will be wrong to the extent of 5 p.ct. or more. Sometimes this can be associated with special types of gas mixtures, at other times the divergence is quite erratic; and the problem in practice is to know when we have encountered one of these exceptional cases. The test can be rapidly made, and for technical work the

effusimeter may undoubtedly be a very serviceable instrument if not trusted too implicitly.

Determination of specific gravities by direct weighing has been practised occasionally for check purposes, but for determinations to be reliable, extreme care is necessary in all manipulation, and in making the observations of auxiliary temperature and pressure measurements. The method is also slow. A special balance is usually required capable of carrying a vessel and counterpoise of at least 500 c.c. capacity, and 1000 c.c. is preferable.

So far, we have not found a method which is superior in accuracy to a calculation of the density from a carefully conducted chemical analysis. It is, of course, slow. Despite the uncertainty as to the composition and density of the unsaturated hydrocarbons and to the fact that other constituents are returned in a conventional manner, the calculated density of typical gas mixtures should not be in error by more than 1 p.ct. Calculated specific gravities have been used for the most part in our work.

Experiments have been carried out in connection with two other methods which are still under investigation as to their suitability for our purpose.

(i) The method described by the Fuel Research Board in Technical Paper No. 5—"An apparatus for the Measurement of Specific Gravity of Gases in Small Quantities" (1922).

(ii) A modification of the Edwards' Gas Balance, as described by the American Bureau of Standards.

APPENDIX I.

List of German papers published since 1912 relating to air-injection and allied problems. Reprinted from the Ninth Report of the Gas Investigation Committee (1923, pp. 227-29).

Strömungsvorgänge an Gasdüsen. H. Pfotenhauer.
J. für Gasbeleuchtung (55), 1912, pp. 997—1002.

Über den Einfluss von Gasdruck und Gasdichte auf die Primärluft im stehenden Auerbrenner. L. Ubbelohde und M. Hofsäss.
On the influence of gas pressure and gas density upon the primary aeration of the upright Auer burner.
J. für Gasbeleuchtung (56), 1913, pp. 149-155.

Der Einfluss der Gasbeschaffenheit auf die Verwendung. K. Bunte.
J. für Gasbeleuchtung (56), 1913, pp. 173-177 and 197-201.
The influence of gas quality upon its utilization. This paper includes a discussion and certain data with respect to aeration and efficiency of different grades of gas.

Methoden zur Beurteilung von Gasdüsen. H. Pfotenhauer.
J. für Gasbeleuchtung (56), 1913, pp. 486-490 and 510-514.
Methods of evaluating gas nipples. An attempt to deal separately with the efficiency of a gas-burner as an injector and the efficiency of the gas nipple in generating the injecting gas stream.

Der Einfluss der Mischrohrform und der Erwärmung auf das Gasluftgemisch in Gasglühlichtbrenner. H. Pfotenhauer.
J. für Gasbeleuchtung (56), 1913, pp. 1069-78, 1097-1102, 1125-1132.
The influence of shape of mixing tube and of preheating therein upon the gas-air mixture in the incandescent gas-burner. The paper is a purely theoretical treatment of these questions.

Erhöhung der Lichtstärke von Gasglühlicht durch Zuführung von Sauerstoff. A. Frank.
J. für Gasbeleuchtung (56), 1913, pp. 1286-87.
Increasing the candle-power of incandescent burners by the supply of oxygen.

Der Bunsenbrenner als Gasinjektor. H. Pfotenhauer.
J. für Gasbeleuchtung (57), 1914, pp. 959-960.
This appears to be a review and summary of the paper contributed by the author to "Wasser und Gas" and extending over the following numbers for the year 1913: No. 21, pp. 467-471; No. 22, pp. 495-499; No. 23, pp. 515-521; No. 24, pp. 543-548; and 1914, No. 1, pp. 14-20.

Über hängendes Gasglühlicht. W. Allner.
J. für Gasbeleuchtung (60), 1917, pp. 460-66.
Upon inverted burners. Contains some data with regard to illuminating powers and degree of aeration.

Über die Strömungsverhältnisse der Zweiluft und Verbrennungsvorgänge bei Hängelichtbrennern. E. Terres und A. Knickenberg.
J. für Gasbeleuchtung (61), 1918, pp. 13-21, 25-33, 39-44.
Upon the relations between the degree of secondary aeration and the processes of combustion in inverted burners.

Über Pressgasbrenner. L. Ubbelohde und K. Zepf.
J. für Gasbeleuchtung (61), 1918, pp. 242, 269, 277.
High-pressure gas-burners. Contains aeration data for these burners.

Gasbeschaffenheit und Lichteffekt. E. Terres und H. Straube.
Das Gas- und Wasserfach (64), 1921, pp. 309-14, 327-36, 348-54, 440-46.
Gas quality and light production. The contents of this paper have been referred to in our Ninth Report, pp. 216-17.

Prof. COBB, in introducing the report, said: The first thing that I would like to mention is a piece of good fortune which has fallen to the Gas Research Sub-Committee. Though Prof. Smithells is no longer Professor of Chemistry at the University of Leeds, he has continued to act as Chairman of the Committee, and to take the same keen interest in all its proceedings; and with your permission, Sir, I will take this opportunity of saying that the movement which the gas industry has so strongly supported for signalizing the services of Prof. Smithells in so many causes, and not least that of the gas industry, has been crowned with complete success.

Arrangements have already been made with Mr. Fiddes Watt, R.A., to paint a portrait of Prof. Smithells, and a sum of over two thousand pounds will remain for the endowment of a Scholarship at the University of Leeds, which will be instituted in accordance with his wishes. As regards the personnel of the Committee, we have lost the services of Mr. H. E. Bloor, who always took a keen interest in its affairs, and his place has been taken by Mr. H. Pooley; otherwise the Committee and its staff remain unchanged.

The research work described in the Eleventh Report of the Gas Investigation Committee before you is a development of that submitted previously in the Ninth Report. It deals with the important subject of aeration and air injection. You will remember that we started this investigation working under the simplest possible conditions and with the simplest possible apparatus made of glass tubes, in order to see what happened when gas jets were injecting air with no complicating influences at work. We have now gone on to make a survey of what happens under the conditions of practice with some burners which may be taken as typical. Two ring burners and the heating burner of a gas fire were chosen. It was found possible to make some deductions (which we hope will be useful) from the experimental results obtained, and the summary of these results has been placed for convenience at the beginning of the report. The way in which the ratio of gas to air altered as the pressure increased, or as the specific gravity of the injecting gas was increased, was studied, and has been carefully stated. These results will be given more fully by Mr. Wood; but simply as illustrating their nature I may say that it was found that with a gas of specific gravity lying anywhere between 0·4 and 0·6 the percentage change in the air-gas ratio is half the percentage change in the specific gravity for equal jet pressure, so that for an increase of 10 p.ct. in specific gravity, the air-gas ratio would increase 5 p.ct. The investigation was then carried further by determining what change in aeration accompanied the various operations which go towards putting a burner into full action. What I mean is this: When the gas jet is turned on, it injects a certain amount of air. This was determined. Then the burner was lighted, and the condition as to aeration was again ascertained. It was found that, in the case of ring burners working under the ordinary conditions of use, the mere act of lighting the burner produces no measurable effect upon the degree of aeration; but when the burner has been alight for some time, its casing warms up, the temperature conditions are altered, the resistance to the passage of the gas-air mixture is increased, and the aeration suffers to some extent. The falling-off was found to be of the order of 10 p.ct. in the burners examined.

I believe that the results so far obtained go some way towards placing our knowledge of this all-important subject on a firmer basis. Plainly the investigation should be extended to other types of burners such as lighting burners—both low and high pressure—and that is proposed.

I think that Mr. Wood, who has been immediately responsible for carrying out this investigation, and his assistant, Mr. Howarth, are to be congratulated, and I say this with more emphasis because, though the literature on the subject is by no means small in volume and has been carefully studied, it has not proved in this instance to be as serviceable as might have been anticipated. The subject is an extremely difficult one to handle; and most of the investigations made might be ranged in two classes. In one class conditions have been simplified to such an extreme that practical application of the results to the conditions existing in burners could not be made at all without making large assumptions. In investigations of the other class, the desire to get at something immediately applicable in practice has led to the premature formulation of working rules which break down when they are tested. It is no easy matter to hit the proper mean in this respect, and even a partial success is something of an achievement.

The Committee would like to express their thanks to the Leeds

Corporation Gas Department, and Mr. C. S. Shapley, their General Manager, for the facilities which they have provided at the Meadow Lane Gas-Works for the carrying-out of this work. They would also again like to thank Mr. James W. Wood, the Research Chemist, who has been immediately responsible for it, and who will present a summary of it for your information and discussion.

Mr. JAMES W. WOOD (Research Chemist), summarizing the report, said: In view of the possible effects of the degree of aeration upon the efficiency in use of gases of different qualities, an investigation of the conditions governing air injection in gas burners was undertaken. At first experiments were conducted with laboratory apparatus of a very simple character, but the results, detailed in our Ninth Report, showed that even for such apparatus the problem of air injection was highly complex. Attention was therefore turned to the examination of a number of typical burners, with a view to ascertaining how these would be affected by changes in the specific gravity of the gas supplied, and in gas rate and pressure. A complete series of aeration tests was carried out with two drilled ring burners of different patterns. Gases of specific gravities of 0·4, 0·5, and 0·6 were used—thus covering a wider range of gas qualities than will usually be encountered in practice—pressures up to 3 in. water-gauge, and gas consumptions up to 25 c.ft. per hour. The burners during experiment were not specially adjusted for each grade of gas, but for all tests the same "fixed" nipple was employed, and the same amount of air-shutter opening. It was found that with these ring burners, for gas of any one specific gravity, the air-gas ratio increased very rapidly with pressure at low pressures, but that the further increase in aeration at gas pressures above 1 in. water gauge was relatively small. Both at equal gas rates, and at equal gas pressures, the air-gas ratio always increased when the specific gravity of the injecting gas was increased. For gases of different specific gravities the air-gas ratio was, however, definitely not simply proportional to the specific gravity of the gas, whether comparisons were made on the basis of equal pressures or equal gas rates. If comparisons were made at equal gas pressures (for either of the burners tested) the amount of air injected in c.ft. per hour was approximately the same for all the gases used—*i.e.*, it was independent of the specific gravity. The volumetric air-gas ratio was nearly proportional to the square root of the specific gravity of the gas, for any given pressure.

When attention was restricted to the specific gravity range 0·4 to 0·6, it was found that the percentage change in the air-gas ratio was approximately one-half the percentage change in specific gravity for the same jet pressure.

It was convenient to make some of our air-injection tests without lighting the gas; and when these tests were repeated under the ordinary working conditions of the burner, with the gas lighted, it was found that the heating-up of the mixture in traversing the burner body caused a reduction in the degree of aeration. This varied with the type of burner in use, being about 10 p.ct. with one burner and 15 p.ct. with the other, comparison being made with the unlighted burner. Tests with a typical 14 in. gas fire yielded results of the same general character, though when a pressure of 1 in. water-gauge was exceeded the air-gas ratio fell slightly, and there was some evidence of the pull of the chimney playing a secondary part in determining the degree of aeration.

The influence of thermal convective forces upon aeration may be expected to modify those due to injection, especially in the case of lighting burners; and this will represent our next line of research.

Subsidiary investigations have been carried out on the measurement of such small pressure differences as occur in burner bodies—hundredths of an inch water-gauge—and on the determination of the specific gravities of mixtures of gases.

Mr. J. FERGUSON BELL (Derby): We are all very grateful for the work that Prof. Cobb has done, and are pleased, as he has pointed out, that the great work which Prof. Smithells has contributed to the advance of the gas industry is going to be signalized by a sum of something like £2000 for the founding of a Scholarship at Leeds University. We are pleased to know that this University is continuing to carry out these important investigations, because it is essential to gas manufacturers to know what is the result of variations of the specific gravity of gas. The investigations which have been carried out on specific gravities ranging from 0·4 to 0·6 indicate that, so far as ordinary pressures are concerned, there is little alteration in the aeration of the flame. I think this is very important, because from time to time gas supplies must vary somewhat in specific gravity. I am glad to know that these investigations are to be continued, for there is no more important subject requiring experimental investigation than the subject of gas and air pressures, in reference to stoves and burners. We know the extent to which gas is now being used for industrial purposes, and therefore it is of the highest importance that we should have sound knowledge of the results of increasing pressure and alterating specific gravity. We are also glad to know that a Corporation like that of Leeds are giving facilities for these investigations, and we thank Mr. Shapley for the assistance he has given, and also Mr. Wood, the Research Chemist, and hope to hear later with regard to further investigations on this subject.

Mr. J. P. LEATHER: Mr. Wood has said that variations in specific gravity do not make a big difference to the amount of aeration, but some of us, perhaps, feel that this is not altogether in accordance with our experience. A few years ago a good many of us were varying the specific gravity and quality of our gas, and found a little difficulty in atmospheric burners in consequence; and when, therefore, we are told that it makes little difference, it does not agree with past experience. The point that interests me is that the specific gravity of a straight coal gas is increased simply by mixing a quantity of heavy hydrocarbons. This experimental work is extremely valuable; and having done a little work of this nature myself, I can say that the results confirm those which I have obtained. At the same time, we must remember that different qualities of gas require different amounts of air, so that the assertion that specific gravity does not alter very much the amount of air injected, does not altogether meet the whole question of how much air a gas will want. Some of the gases that are now being used in the country may not require more than about 4 parts of air to 1 of gas, whereas very high quality gases may want (say) 6 parts. I have only mentioned these figures to illustrate the point that different qualities of gas may require very different quantities of air, and therefore specific gravity is not the only thing. In experimenting, of course, it is necessary to separate the various elements and work on one at a time; and this report certainly is valuable, and I am pleased to express my appreciation of it.

Mr. W. NEWTON BOOTH (Woolwich): One is surprised at the amount of material required to be digested in order to make any remarks on this report, and the time I have had has not been sufficient for a proper study of the results on the lines I should like to discuss it. I would, however, like to associate myself with the remarks made by Mr. Ferguson Bell as to the great debt which the industry owes to Prof. Smithells and to the many workers at Leeds on this subject. It seems to me that the subject of the aeration of gas burners divides itself naturally into two distinct phases; and so far as I have been able to study the results obtained, the report deals very much more fully with one phase than with the other. The two phases are, first of all, the design of a suitable burner for any given conditions, and, secondly, from the point of view of the gas supplier, knowing what the result will be of any variations of pressure and quality of the gas. From the point of view of a designer of burners, which personally appeals to me most, I should like to have an opportunity of analyzing the results which are being obtained by the Committee in the following way. The injection of air through a burner is governed, probably, by three factors: One is the momentum of the gas stream issuing from the jet, which is a thing you can calculate fairly easily if you know the pressure of the gas, &c.; the second is the amount of momentum which can be added to the air before it is mixed with the gas; and the third is the resistance of the burner arrangement itself to the flow of the resulting mixture. This resistance has three different forms, and they result in two mathematical expressions. There are the resistances which are proportional to the square of the velocity of the gas moving, and there are other resistances which are, to a large degree, proportional to the velocity of the gas itself. I have taken the figures of the first report and have analyzed them in this way, and find that they are consistent with the simple theory of the injection of the burners. I should like to see these results amplified by their application to the more complicated burners which are used in practice. With regard to alterations in gas quality, the most important thing is the point which was made by Mr. Leather, and with which I agree entirely—*i.e.*, that alterations in the air requirements of the gas have a very much greater effect on burner performance than an alteration in the actual amount of air which is injected by the burner. Variation in specific gravity and in pressure of the gas have much less effect on the actual burner results than alterations on the air-consuming properties of the gas.

Dr. E. W. SMITH (London): There is one suggestion I should like to make, and that is that the Committee should endeavour to guide engineers by presenting a form of introduction to this report which would indicate in a sort of theoretical way all the conceivable effects which might be brought about by variations in specific gravity. If there were a proper presentation to the industry of the whole subject, in the manner I have indicated, many of the points might be the subject of further experimental work by the Committee. I think we should all appreciate a really good picture of the effect of specific gravity, not only on a theoretical, but on a really practical basis.

Mr. WOOD, replying to the discussion, said: I do not know whether I am in order in associating myself with the remarks made in connection with Prof. Smithells and the appreciation of his services which has been expressed by others; but in his position as Chairman of the Research Sub-Committee, it has always been a pleasure to work under him, and to consult him on any points in connection with the investigation. Turning to technical points for a moment, it is fully appreciated that different kinds of gas require different amounts of air for their complete combustion, but the point which is not agreed upon is whether it is ever necessary or advisable to supply the whole of that air to the burner as primary air. The results that we have obtained in our experiments did not show exactly that there was no variation in aeration with specific gravity of the gas; but the variation

was very much smaller than might have been expected. Some figures which were published by the American Bureau of Standards showed the facts on this point in a very marked way. A certain burner was taking-in free air and gas in the proportion of 4 volumes of air to 1 of gas. The gas quality was then changed to that of a gas mixture requiring something like half the previous quantity of air—*i.e.*, 2 to 2½ volumes. If the construction of the burner had not been altered in any way, it was assumed that the burner would be capable of taking-in the whole of the air required for the combustion of the gas as primary air. When the attempt was made to light the burner, it was found that the air shutter had to be closed very considerably, and that though as a mechanical appliance for injecting air the burner would take-in the whole of the air required, and, in fact, more air than was required for combustion, it was necessary to throttle-down the air opening; and the quantity actually taken-in with the gas to produce a flame suitable for combustion in that burner was something like 30 p.ct. of the air theoretically necessary for the combustion of that gas. With regard to the remarks of Mr. Booth, in one of the appendices or sections of our last report—the Ninth Report—we made some attempt to discuss papers dealing with equations of momentum; and it was largely because we could not reach any really satisfactory conclusion in that respect, with regard either to equating the momentum or expressing the momentum of the mixture as a proportion of the momentum of the gas issuing from the jet, that we reverted once more to experimental work. A great many people think we ought to be able to work simply on lines of mechanics in equating the momentum, but the answer to that is that when we tried the experiment in practice we found it is not the case. Distribution of energy and distribution of momentum in the mixture does not come about by a process of simple impact, and the various losses which take place in the burner casting represent a very large proportion of the whole of the available energy, Hence, if we attempt to assume anything in the nature of a correction factor, or anything like that, to express momentum of a mixture as a proportion of the momentum possessed by a jet, we come to grief very soon, Dr. Smith's remarks are very interesting, but I think there was an opening section in the Ninth Report which detailed some of the possible effects that might have been anticipated from variations in the specific gravity of the gas. As that is twelve months ago, it may have been overlooked. Mr. Lacey has dealt in considerable detail with the aspect of specific gravity as it affects distribution and the pressure available at the consumers' appliances.

Prof. COBB: Mr. Booth has said what is obviously true, that the amount of matter with which this report is loaded—I hope not overloaded—is very considerable, and that for its proper consideration more time is necessary than it has been possible to give him or the members in general. I hope, however, that Mr. Booth, after further consideration, will be able to send in a contribution to the discussion dealing with the report, and, if possible, with some of the analyses of our other results which he has found himself able to make. The same invitation is extended to other members of the Institution in connection with this report and all the other reports which we shall have the privilege of bringing forward.

The PRESIDENT: I am quite sure that the extremely valuable fundamental work that has already been achieved, and that will be achieved in the future, will have results of very great value to the industry. It is a subject which may not make a wide appeal to many of the members, but all will realize that the work is of fundamental value, and its application must result in benefits in the design of appliances, and so prove to be of very direct importance and value to the industry. I formally move the adoption of the report.

Mr. C. F. BOTLEY (Hastings): I have great pleasure in seconding the motion. The subject is one the importance of which I should say is not fully appreciated, but it has more than a passing interest to everybody in the industry, and, when applied, will prove of very great value, particularly in the design of apparatus. I, for one, have felt, in dealing with the distribution of gas, that though we have varied in the course of manufacture, as we have to do, the composition and pressure of our gas, we have always been a little apprehensive of what the effect might be on the consumer, even though we have had no practical evidence. This research, however, will either prove preconceived ideas wrong or it will prove them right, and I therefore trust that every member of the Institution, whether the subject appeals to him or not at the moment, will appreciate the value of the work being done.

The report was then adopted.

INSTITUTION BENEVOLENT FUND.

The Annual General Meeting of the Benevolent Fund of the Institution was held on Wednesday morning. The PRESIDENT (Mr. Samuel Tagg) was in the chair.

The PRESIDENT: The minutes of the last meeting are to be submitted for confirmation.

Mr. SAMUEL GLOVER: I propose that the minutes be taken as read and confirmed.

Mr. OCTAVIUS THOMAS (Pentre) seconded, and it was agreed to.

The PRESIDENT: I will ask Mr. Dunn to read the annual report of the Committee of Management.

The HON. SECRETARY (Mr. Walter T. Dunn) then read the report of the Committee for the year 1923-24—see p. 740 of the "JOURNAL" for June 11.

The PRESIDENT: In moving the adoption of the report, I should like just to say a word or two regarding the value of the work which the Committee of Management are enabled to perform. There are a considerable number of beneficiaries who regularly receive help from this fund, and in every case it is in circumstances where help is most urgently needed, and where the sum which the Committee are enabled to grant really makes all the difference between possibly abject poverty and some reasonable condition, and if the benefits of the fund to those who are in poor and distressed circumstances were only more widely known, I am sure we should have a more generous response to appeals for the fund, and a wider one. I would like you all to try and influence your friends to become annual subscribers. The money is faithfully applied, and there can be no better object found for it. I have pleasure in moving the adoption of the report of the Committee of Management for the year 1923-24.

Mr. C. F. BOTLEY (Hastings): I have much pleasure in seconding this motion. I am afraid sometimes the attractions to be found outside the building are more than those of attending to the business of the Benevolent Fund. But some of us must interest ourselves in this matter, which is so vital; and it is gratifying to find there is some greater response to appeals than there has been in the past, though even now, if you look at the report, you will see that assistance granted to widows, orphans, and members amounted to £405, while subscriptions totalled only £280. If it had not been for the care with which the fund has been administered in the past, and for the donations received from time to time, we should not be self-supporting. We are still a long way from where we should like to be. The ideal would be that every member of the Institution should in some measure support the Benevolent Fund. That is the ideal, and we shall not be satisfied until we reach it. We never know what may happen to any of us, and what greater calls may come upon the fund. So far as I have been associated with it, I have always found that those who have applied have received the assistance that the President has mentioned, and it has made all the difference to them in carrying on in sometimes unhappy circumstances. What is being done by this fund is of real benefit to those who participate in it. (Applause.)

Mr. DANIEL IRVING (Bristol): I should like to add one or two words before the resolution is put. I wish to express our thanks to the Committee of Management for their fostering care and judicious administration of this fund. The balance-sheet speaks for itself. But I particularly rise to express our very grateful thanks to our esteemed friend Mr. Surridge, for his munificent donation of one hundred guineas. In addition to this handsome gift, we must not overlook the very generous support that the fund receives from the various Associations.

Mr. P. S. HOYTE (Plymouth): May I suggest that when the room is a little fuller you might, Sir, repeat the appeal you have just made? Probably practically everyone attending this meeting of the fund is a subscriber already. It is the non-subscribers that we want to reach.

The resolution was then unanimously carried.

The PRESIDENT: The two vacancies on the Committee of Management have been filled by the appointment of Mr. Thomas Goulden and Mr. G. S. Frith. They will take the places of Mr. Herbert Lees and Mr. Frank Prentice. Unless there is anyone desirous of raising any other point regarding the business of the Benevolent Fund, that closes the meeting.

TWELFTH REPORT OF THE RESEARCH SUB-COMMITTEE OF THE GAS INVESTIGATION COMMITTEE.

WASTE-HEAT BOILERS AND VERTICAL RETORT INSTALLATIONS.

[For "General Introduction" see the Eleventh Report.]

INTRODUCTION AND SUMMARY OF RESULTS.

The inquiry into the thermal and chemical efficiencies of methods of manufacture of different grades of gas was commenced by an investigation of the process of steaming the charges in the retorts of the continuous vertical installation at the works of the Bothwell and Uddingston Gas Company. The results of the Uddingston tests, which appear in the Fourth Report, proved that with proper control of the conditions, considerable advantages are to be gained by *moderate* steaming. The thermal efficiency of gas production rose from 54·4 p.ct. without steam, to a maximum of 62·1 p.ct. with steam. It was afterwards calculated (*vide* Sixth Report) that if the steam required for the retorts could have been raised in waste-heat boilers, the efficiency of 62·1 p.ct. would have been increased by approximately 6 p.ct. to 68·5 p.ct.

The next step in the investigation, described in the Sixth Report, was carried out at the Adderley Street Works of the Birmingham Gas Department, with the object of determining the efficiency of production of blue water gas as ordinarily practised in a plant without waste-heat boiler. It was found that, taking into account the steam required for the generator and turbo-blower, the efficiency of gas production averaged 46 p.ct., and it was calculated that if the steam required had been raised by means of a waste-heat boiler, the efficiency of 46 p.ct. would have been increased to 56 p.ct. This conclusion was supported by the results given in the Seventh Report, which describes an investigation of the manufacture of carburetted water gas in a Humphreys and Glasgow plant with attached waste-heat boilers. The amount of water evaporated in the waste-heat boilers was sufficient to supply the steam required for the generators, turbo-blower, and auxiliary plant, under the conditions of the tests.

It was pointed out in the Sixth Report that an alternative method of diminishing the loss of heat due to the potential heat of the blast gases in the manufacture of blue water gas might be to reduce the amount of carbon monoxide carried away up the stack, by changes in the method of operation of the plant, in so far as such changes could be made without prejudice to the efficient production of water gas during the run periods. This problem was investigated at the Adderley Street Works of the Birmingham Gas Department, and the results obtained are described in the Tenth Report. After a number of preliminary trials, several complete tests were carried out under different conditions. In one of the tests, the loss of heat due to the potential heat of the blow gas was reduced to 11·5 p.ct. of the total heat supplied as against 20 p.ct. in the Sixth Report tests. The reduction of 8·5 p.ct. in the loss from this source, however, was achieved at considerable expense in other directions. It was finally concluded that the manufacture of blue water gas by the intermittent process can be carried out more efficiently and with a greater output of gas per day when the ratio of carbon dioxide to carbon monoxide in the blow gas is about 0·9 than when this ratio is greater than unity; in other words, the amount of carbon monoxide in the blow gas should be rather more than the amount of carbon dioxide. From calculations of the heat available for use in a waste-heat boiler, it was also concluded that, even with the installation of a waste-heat boiler, the intermittent process would be more efficient under such conditions that the blow gas contained rather more carbon monoxide than carbon dioxide.

It will be appreciated from this brief account of the work on the manufacture of different grades of gas, described in the reports previously issued by the Research Committee, that the inquiry would not be complete unless it included an investigation of the heat recoverable in a waste-heat boiler attached to an installation of continuous vertical retorts. The Research Committee was therefore pleased to accept the generous offer of the Birmingham Gas Department to grant the necessary facilities, and to allow an investigation to be conducted on the water-tube waste-heat boilers attached to the installations of Woodall-Duckham continuous vertical retorts at their Windsor Street works. The method of conducting the investigation and the results obtained are described in this Twelfth Report. Since the object was to determine the amount of steam which could be raised in a waste-heat boiler attached to a typical installation of continuous vertical retorts, when both the retort installation and the boiler were being operated under the conditions of ordinary works practice, the usual routine of operation was adopted throughout the investigation.

The coal carbonizing installation at the Windsor Street Works consists of six separate ranges, designated A, B, C, D, E, and F, of Woodall-Duckham continuous vertical retorts. With the exception of Range D, each range is made up of eleven settings of four five-ton retorts. Each setting has a separate producer, a main coal bunker and a coke bunker, so that a complete range includes eleven producers, eleven coal bunkers, and eleven coke bunkers. Attached to each range there is a Babcock and Wilcox water-tube waste-heat boiler through which the waste gas is passed before entering the chimney. Range D, however, contains 32 seven-ton retorts. There are eight producers in this range, four situated at each end, two coke bunkers and two large coal bunkers, and there is an attached water-tube waste-heat boiler. The retorts of Range D, which had been in operation for a period of five years without resetting, were not in good condition. The waste-heat boiler, however, appeared to be in good working order, and the dispositions of the producers and of the coal and coke bunkers were such that the examination of the producer gases, and the determinations of the weights of coal and coke used, presented fewer difficulties than in the case of any of the other ranges. In view of these and other considerations, and since the main object was to examine the performance of a waste-heat boiler, it was decided to select Range D for the first part of the investigation.

Preliminary experiments were first made with the object of devising satisfactory methods of obtaining the essential data. Two tests, each extending over a period of five days, were then conducted, and the whole of the information considered necessary was procured. From the data obtained, heat equations were constructed for the purpose of ascertaining the volumes of waste gases passed through the boiler per hour. From these volumes and the known compositions of the gases, the equivalent weights of carbon were then determined. These weights should have been approximately the same as the weights of carbon gasified in the producers, provided that no leakages of gas through the retort walls or past the dampers closing the flue leading direct to the chimney had occurred. Leakages of waste gas into the retorts or past the by-pass dampers direct to the chimney would cause the weight of carbon in the gas passed through the boiler to be less than that gasified in the producers. On the other hand, leakages of coal gas, &c., from within the retorts or of waste gas from the chimney side of the by-pass dampers back again into the boiler would result in a greater weight of carbon in the gas passed through the boiler. The weights of carbon actually obtained were as follows:

Weights of Carbon. Pounds per Hour.

Test No.	1.	2.
Range	D	D
Carbon in gas passed through boiler	2330	2180
Carbon gasified in producers	2021	1862
Difference	309	318

These figures show that the volumes of gas passed through the boiler per hour were more than correspond with the weights of carbon gasified in the producers. A method involving the construction of carbon, water, and heat equations was therefore devised for the purpose of ascertaining the approximate amounts of the various leakages which must have taken place. From these equations it was found that

approximately one-third of the difference in carbon weights in Test 1 and two-thirds of the difference in Test 2 were due to leakages of waste gas past the by-pass dampers and back again into the boiler. The remaining weights of carbon therefore represent the excess of leakages of coal gas, &c., from within the retorts over any leakages of waste gas which may have occurred through the retort walls in the opposite direction. The equations also proved that in addition to leakage of air into the waste-gas flues, water had entered an underground flue.

Since the performance of the waste-heat boiler attached to Range D had been influenced, among other factors, partly by leakage of gas through the retort walls and partly by the leakage of water into an underground flue, a further test was carried out on Range E, the retorts of which had been reset early in 1923, and in which the waste-gas flues are all situated above ground level. The weight of carbon gasified in the producers in this third test was 2520 lbs. per hour, compared with 2810 lbs. in the gas passed through the boiler as deduced from a heat equation. The arrangement of the flues and boiler of this range is such that it was not possible to secure data which would enable the construction of the three simultaneous equations for carbon, water, and heat as in the two tests on Range D. Comparisons of the compositions of the waste gases and the producer gases, however, led to the conclusion that the leakages of gas (if any) through the retort walls were small; it would thus appear that the 290 lbs. carbon difference in Test 3 is to be accounted for mainly by leakages past the by-pass dampers.

The principal results obtained during the three tests are given in the following table:

Test No.	1.	2.	3.
Range	D	D	E
Boiler gauge pressure, lbs. per sq. in.	134	131	132
Quality of steam, dryness fraction	0·957	0·956	Dry
Superheat in °C.	..	..	126
Equivalent evaporation from and at 100° C.—			
Lbs. per 100 lbs. dry coal carbonized	39·4	42·5	53·4
Lbs. per 100 lbs. coal as supplied to retorts	37·5	40·1	50·6
Lbs. per lb. dry coke to producers	2·97	2·85	3·41
Temperature of gases at inlet boiler, °C.	611	631	695
Net thermal efficiency of boiler (*vide* text)—			
(*a*) As per cent. of heat of gases at inlet boilers	37·4	37·4	44·7
(*b*) As per cent. of heat of gases in flues 1 and 2 (Diagram I.)	38·7	39·9	..

The boiler attached to Range E included an integral superheater, with the result that the temperature of the steam was raised to 306° C. at a gauge pressure of 132 lbs. per sq. in.—*i.e.*, the amount of superheat was 126° C.

The amounts of water evaporated in the boilers during the three tests were equivalent to evaporations from and at 100° C. of 39·4, 42 5, and 53·4 lbs. per 100 lbs. of coal (dry basis) carbonized, or 2·97, 2·85, and 3·41 lbs. per lb. of coke (dry basis) supplied to the producers.

The net thermal efficiencies, item (a), represent the amounts of heat utilized in raising the net weights of steam available (due allowances being made for the power required for the fan motors and the boiler feed pump) as percentages of the heat contents of the gases at the inlets to the boilers. The efficiency during Tests 1 and 2 was 37·4 p.ct. The higher efficiency of 44·7 p.ct. during the third test was undoubtedly due mainly to the higher average temperature at which the gases entered the boiler.

The net efficiencies given against item (b) for range D represent the same amounts of heat expressed as percentages of the heat values of the gases in the vertical down flue, positions 1 and 2 of Diagram I. The construction of the flues of Range E is such that the corresponding figure for Test 3 cannot be given.

Expressed as percentages of the heat values of the fuel supplied to the producers, the net quantities of heat recovered were 20·7 p.ct., 20 p.ct., and 24·2 p.ct. respectively in the three tests. In the absence of waste-heat boilers it would have been necessary to raise the same amounts of steam in boilers fired with solid fuel. On the basis of an efficiency of 70 p.ct., the solid fuel boilers would have consumed 8·6 tons of coke per day in Test 1, 8 tons in Test 2, and 12·1 tons in Test 3, the qualities of the coke being the same as those actually supplied to the producers. These weights therefore represent the amounts of fuel saved per day by the waste-heat boilers, quite apart from a reduction in labour charges. It has been calculated that the amounts of heat recovered in the waste-heat boilers in this investigation would bring up the efficiencies of gas production in normal working with continuous vertical retorts by about 6 p.ct.—*e.g.*, from 60 p.ct. to 66 p.ct.

The leakages of waste gas past the by-pass dampers back again into the boilers cannot have had any marked influence on the amounts of steam raised, since these gases entered the boilers at temperatures not very much lower than those at the outlets of the boilers. From the compositions of the samples of waste gas taken at different points, however, it has been shown that large volumes of air must have leaked into the boiler settings and into the waste-gas collecting flues. It has also been concluded that if leakages of air were eliminated, the gases passed through the boilers should contain approximately 18 p.ct. carbon dioxide. The gases at the outlets of the boilers actually contained only 11·3 p.ct. carbon dioxide in Test 1, 11·2 p.ct. in Test 2, and 10·3 p.ct. in Test 3. The volumes of air which would be required to bring about the necessary dilutions of carbon dioxide from 18 p.ct. have been calculated; and in addition the amounts of heat carried by these volumes of air at the temperatures at which they left the boiler have been deduced. These amounts of heat, expressed as percentages of the heat values of the gases which entered the boiler, are 12·3 p.ct., 13·6 p.ct., and 14 p.ct. respectively in the three tests. If air leakages were eliminated, the whole of these quantities of heat would not necessarily be utilized in raising steam, but large proportions would be recovered, with resulting improvements in the efficiencies of the boilers. The prevention or reduction of air leakage is therefore worthy of consideration.

THE INSTALLATION OF CONTINUOUS VERTICAL RETORTS AT THE WINDSOR STREET WORKS OF THE BIRMINGHAM GAS DEPARTMENT.

The coal carbonizing installation at the Windsor Street Works of the Birmingham Gas Department consists of six separate ranges, designated A, B, C, D, E, and F, of Woodall-Duckham continuous vertical retorts. With the exception of Range D, each range is made up of eleven settings of four retorts, and each retort has a nominal carbonizing capacity of five tons per day. A range of retort-settings therefore contains 44 retorts, and has a total nominal capacity of 220 tons of coal per day. Each setting has a separate producer, a main coal bunker, and a coke bunker, so that a complete range includes eleven producers, eleven coal bunkers, and eleven coke bunkers. Attached to each range, there is also a Babcock and Wilcox water-tube waste-heat boiler, through which the whole of the waste gas from the range is passed before entering the chimney.

Range D contains 32 retorts, each with a nominal capacity of seven tons of coal per day, so that the total capacity of the range is 224 tons per day. There are eight producers, four at each end of the range, two coke bunkers, and two large coal bunkers; and there is an attached water-tube waste-heat boiler for dealing with the whole of the waste gas. The retorts of this range, which had been in operation for a period of five years without resetting, were not in good condition. The waste-heat boiler, however, appeared to be in good working order, and the dispositions of the producers and of the coal and coke bunkers were such that the examination of the producer gases and the determinations of the weights of coal and coke used, during any given test period, presented fewer difficulties than in the case of any of the other ranges. In view of these and other considerations, and since the main object of the inquiry was to examine the performance of a waste-heat boiler, it was decided to select Range D for the first part of the investigation. A preliminary trial was conducted, and then followed two tests in which the whole of the information believed to be necessary was procured. From the data obtained during these two tests it was found that the performance of the waste-heat boiler had been influenced, among other factors, partly by leakages of gas through the retort walls into the combustion flues, and partly by the leakage of water into an underground waste-gas flue, through which the waste gas travelled before entering the boiler. A further test was therefore carried out on Range E, the retorts of which had been reset early in 1923, and in which the waste-gas flues are all situated above ground level.

Since the investigation described in this report was carried out on Ranges D and E, more detailed descriptions of these two ranges, with diagrams, are given.

RANGES D AND E.

General Arrangement.—The general arrangement of the two Ranges D and E and of the attached waste-heat boilers is shown in plan in Diagram I., in which the arrows → denote the direction of flow of the waste gases when the boilers are in circuit. From the diagram it may be seen that the two ranges differ considerably from one another in design.

Range D is built in two exactly similar sections, each section containing 16 retorts, four producers, and two waste-gas collecting flues built within the range. The waste gases travel from the four flues within the range into a flue with a central dividing wall and situated between the two halves of the range. The gases then travel downwards through a vertical flue with a dividing wall, before they enter a common underground flue. When the boiler is not in operation, the two dampers separated by a brick pier and situated in the flue leading direct to the chimney are opened, and the damper in the short branch flue to the boiler is closed. When the boiler is in operation, then the two dampers in the flue leading direct to the chimney are closed, and the boiler damper is opened. After passing through the boiler, the waste gas travels from the fan into an underground flue and thence to the chimney.

Range E is built in two sections, one of which contains five settings of four retorts, and the other six settings of four retorts. Each setting has a separate producer and two waste-gas exits into a common waste gas flue built outside the range and extending almost its entire length. When the waste-heat boiler is not in circuit, the waste gases travel from the main waste-gas flue through four branch flues into two chimneys, the four necessary control dampers being open, and a damper in a common vertical flue to the boiler being closed. When the boiler is in circuit, then the two branch flues to each of the two chimneys are closed, and the damper in the vertical down flue from the horizontal main flue is opened. The gases enter the boiler at ground level, and the main waste-gas flue and the branches to the chimneys are above ground level. The waste gases are drawn through the boiler by means of a fan, and thence they travel into a metal flue so arranged that the gas is divided into two streams to enter the two chimneys, as shown in the diagram.

The boilers for the two ranges are situated side by side; and the positions of the boiler feed pump, the water meter, and the boiler feed tank used solely for the purpose of the tests, are shown in the diagram by the letters P, M, and T respectively.

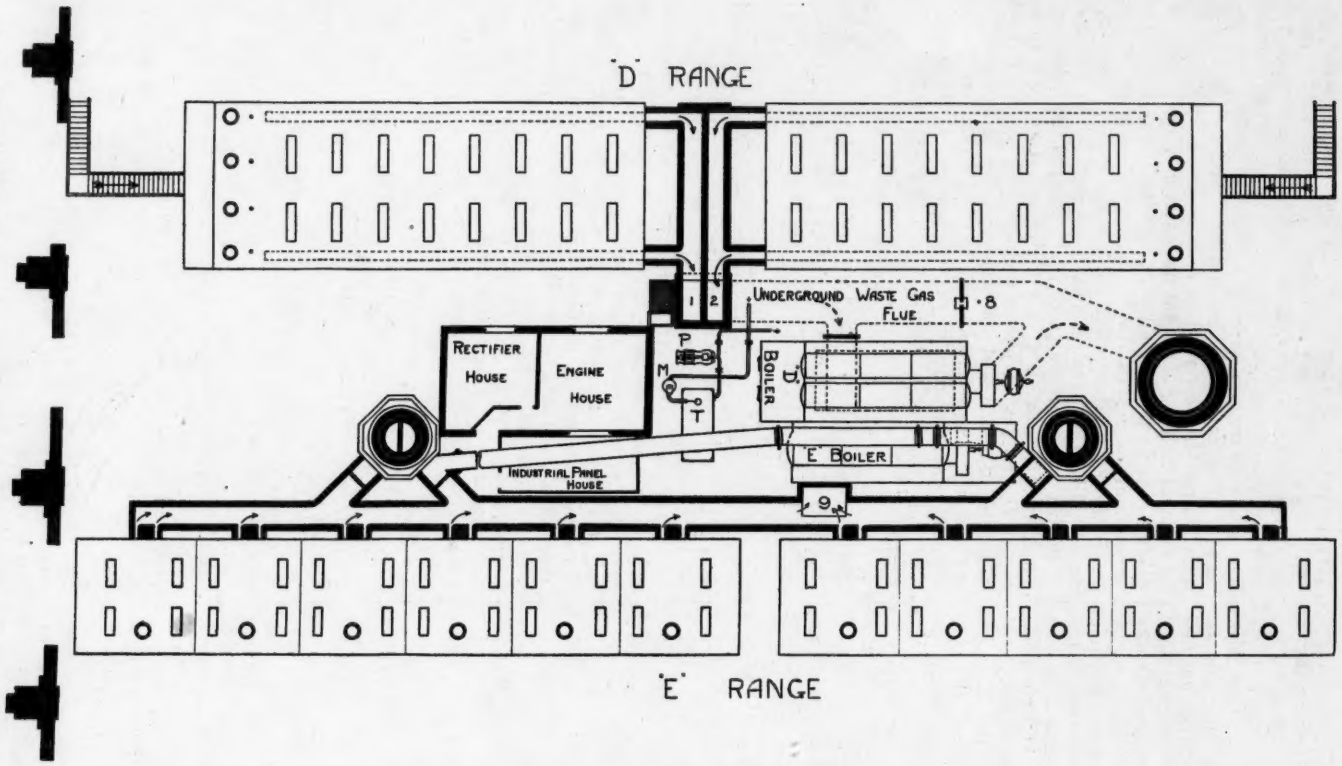


DIAGRAM I.

Plan of Ranges D and E of Continuous Vertical Retorts and Waste Heat Boilers at Windsor Street Gas-Works, Birmingham.

RANGE D.

It has already been pointed out that Range D* is built in such manner that there are two similar sections, each containing 16 retorts, four producers, and two waste-gas collecting flues built within the range. Each retort has a nominal capacity of seven tons of coal per day. The retorts are about 26 ft. in length, and of rectangular tapered shape; the major axis varies from 5 ft. 7⅛ in. at the top to 6 ft. 6 in. at the bottom, and the minor axis from 7 in. to 1 ft. 6½ in. The taper is accentuated about the upper portions of the retort with the object of assisting the descent of the coal while in a semi-plastic and expanding condition. The coal is fed into the retorts by gravity from small hoppers at the top, which have a capacity sufficient for several hours'

* This range was constructed in 1919; modifications in design have been introduced in later installations.

supply. It is usual to charge these every two hours from the main coal bunkers through close-fitting cylindrical valves. The main coal bunkers have a capacity sufficient for 48 hours. The rate at which coal falls by gravity into the retorts is regulated by the rate at which coke is mechanically extracted at the bottom.

A cast-iron hopper with a curved back plate is attached to the bottom of each retort. The extracting device in the form of a helical toothed roller (built in sections) is situated at the bottom of this curved plate. The shaft of the extractor roller projects through a gland in the side of the hopper, and is fitted with a driving wheel grooved in its periphery. A rotary motion is imparted to the extractor roller by an eccentric wedge-shaped pawl attached to a rocking arm and operating as a toothless ratchet. The length of stroke and speed of rotation can be varied by means of a screw adjustment to each retort. The coke hopper below the extracting device is of a capacity sufficient for several hours' discharge of coke. The bottom door of the coke hopper is sealed in water to a depth of about 4 in. The coke, which is never in actual contact with the water seal, is quenched by the introduction of a fine water spray immediately below the extractor.

According to the method of operation now in practice in Birmingham, steam is admitted to the retorts through pipes situated above the coke extractors. The amount of steam is controlled by means of valves, pressure gauges, and disc orifices of the desired size.

The arrangement of the range and the method of heating are shown in Diagram II., which gives longitudinal, plan, and cross-sections through different portions of one-half of the range. The walls of the retorts are formed of grooved and tongued bricks, which are panelled at the back so that a large surface of material is presented to the heating gases. The six vertical combustion flues to each retort are separated by division walls of tongued and grooved bricks bonded into the retort and into the back walls of the flues. The flues are so arranged that the heating of each retort is under complete and separate control.

The producer gas from each pair of producers enters a main producer-gas flue, from which the gas is drawn for heating a row of eight retorts. From Diagram II., in which the flow of producer gas is denoted by arrows □→, it may be seen that the vertical combustion chambers are supplied at the top from the main producer-gas flue, which is reduced in size after four retorts have been supplied. The primary air for the producers is admitted through ports along the outside walls of the range, and is preheated by passage to the middle of the range near the bottom of the retorts. No steam is supplied to the producers, but water is made to flow on to the firebars.

The secondary air (denoted by arrows →) is preheated by passage through tubular recuperators before travelling vertically upwards to the combustion flues. After leaving the bottom of the combustion chambers, the waste gas from each retort travels upwards to enter a waste gas collecting flue for each group of eight retorts. This waste-gas collecting flue is increased in size after the gases from four retorts have been collected.

The waste gases from the four flues built within the range enter a flue situated between the two halves of the range. They then travel downwards to an underground flue before entering the waste-heat boiler, as shown in Diagram I., and as already described.

Waste-Heat Boiler, Range D.—The waste-heat boiler attached to Range D (which was designed with the intention that it should deal with the waste gases from a group of 48 seven-ton retorts) was installed early in 1919, when the range itself was erected. It is a water-tube boiler of the well-known Babcock and Wilcox pattern, but includes neither economizer nor superheater. From Diagram III. it may be seen that the boiler is fitted with two steam and water drums. It contains 196 tubes set at an angle; and each tube is 18 ft. long and 4 in. in diameter. The total area of the heating surface is 4315 sq.ft. The boiler fittings include two gauge glasses, a steam gauge, a safety valve, an isolation valve, and warning devices for high and low water levels. The necessary manholes are provided, and the parts are easy of access for purposes of cleaning. Calibrations of the steam drums have shown that a movement of 1 in. about the middle position of the gauge glasses is equivalent to approximately 50 gallons per drum—*i.e.*, 100 gallons per inch for the two drums. There are arrangements for hand-firing the boiler with solid fuel, if it should be desired at any time. The grate area is approximately 60 sq.ft. The permissible working pressure is 135 lbs. per sq.in.; the boiler was last submitted to a hydraulic test of 275 lbs. per sq.in. at the time of its erection. According to the last report (October, 1923) of the insurance company's inspector, the boiler was generally in good condition, but the plates and headers in tubes were pitted a little in places. The quality of the feed water was described as fair.

Water Supply.—A supply of clear water is normally obtained from an artesian well situated on the works. The water is first pumped to an elevated tank, whence it runs by gravitation to the desired points in different parts of the works. In ordinary practice, a quantity of the water which has been heated to about 140° Fahr. (60° C.) by passage through the condensers is run into a boiler feed tank situated in the retort-house; it is then forced by means of a Weir pump to supply the whole of the waste-heat boilers in operation. For the purpose of the investigation described in this report, it was necessary to isolate the boiler under test by breaking the connections on the boiler feed service and installing a separate tank, a water meter, and a boiler feed pump. The positions in which these were installed are shown in Diagram I.

Mechanical Draught.—The waste gases are drawn through the boiler, and the necessary "pull" in the waste-gas flues of the settings is ensured by means of a Sirocco fan installed at the outlet end of the boiler (*vide* Diagram III.). The diameter of the circular inlet of the fan is 3 ft. 3 in., and the discharge outlet is 2 ft. square. The fan, which has water-cooled bearings, is direct-coupled with a 25 H.P. motor made by the British Thomson-Houston Company, Ltd. This is of the induction type with slip-ring rotor, and is designed for a speed of about 730 revolutions per minute, with a current potential of 440 volts, alternating 50 periods per second, and three-phase. The electric power for the works is generated by means of either of two 400 KW. sets (one acting as a spare) which include continuous current generators and B.T.H. Curtis turbo-alternators (condensing type), designed for a speed of 3000 revolutions per minute, and a steam pressure of 145 lbs. per sq.in.

Chimney Range D.—The waste gases pass from the outlet of the fan into an underground flue, and thence to the brick chimney, which is 130 ft. high, 7 ft. diameter at the top, and 8 ft. 9 in. diameter at the base.

RANGE E.

This range was erected in 1912, and the retorts were last reset during 1923, but on this occasion the recuperator work was not renewed. As already mentioned, the range includes eleven settings of four retorts, each of a nominal capacity of five tons of coal per day. Each setting has a separate producer, and there are two waste-gas exits into a waste-gas collecting flue built outside the range. The retorts are similar in design to those of Range D, but of smaller dimensions. They are about 25 ft. in length and of rectangular tapered shape; the major axis varies from 3 ft. 11 in. at the top to 5 ft. 3 in. at the bottom, and the minor axis from 7 in. to 1 ft. 6½ in. The arrangements of the coal-feed hoppers, the coke extractors, and the coke discharge hoppers are similar to those already described for Range D.

The method of heating each setting is shown in Diagram IV. There are eight vertical combustion flues for each retort, as against six in Range D. The producer gas rises upwards through vertical flues (as indicated by arrows □→) to horizontal flues which supply the combustion chambers at the top. The secondary air (denoted by arrows →) is preheated by passage through recuperators situated between waste-gas flues. It will be observed that these recuperators are different in type from those of Range D. After leaving the combustion chambers, the waste gases travel upwards and then downwards before entering the main waste-gas flue built outside the range.

The desired quantity of steam is admitted to the retorts through flues arranged for the purpose.

Waste-Heat Boiler, Range E.—The Babcock and Wilcox water-tube boiler attached to Range E was installed in 1922, and was first put into operation during the early part of 1923. It differs in several respects from the waste-heat boiler attached to Range D. There is only one steam and water drum (*vide* Diagram V.), but there is a superheater integral with the boiler. No provision is made for firing with solid fuel. The boiler contains 160 tubes, each 16 ft. long and 4 in. in diameter. The area of the heating surface exposed to water is 3176 sq.ft., and the surface area of the super-

Submitted to and approved by Messrs. Woodall-Duckham Vertical Retort and Oven Construction Co (1920), Ltd.

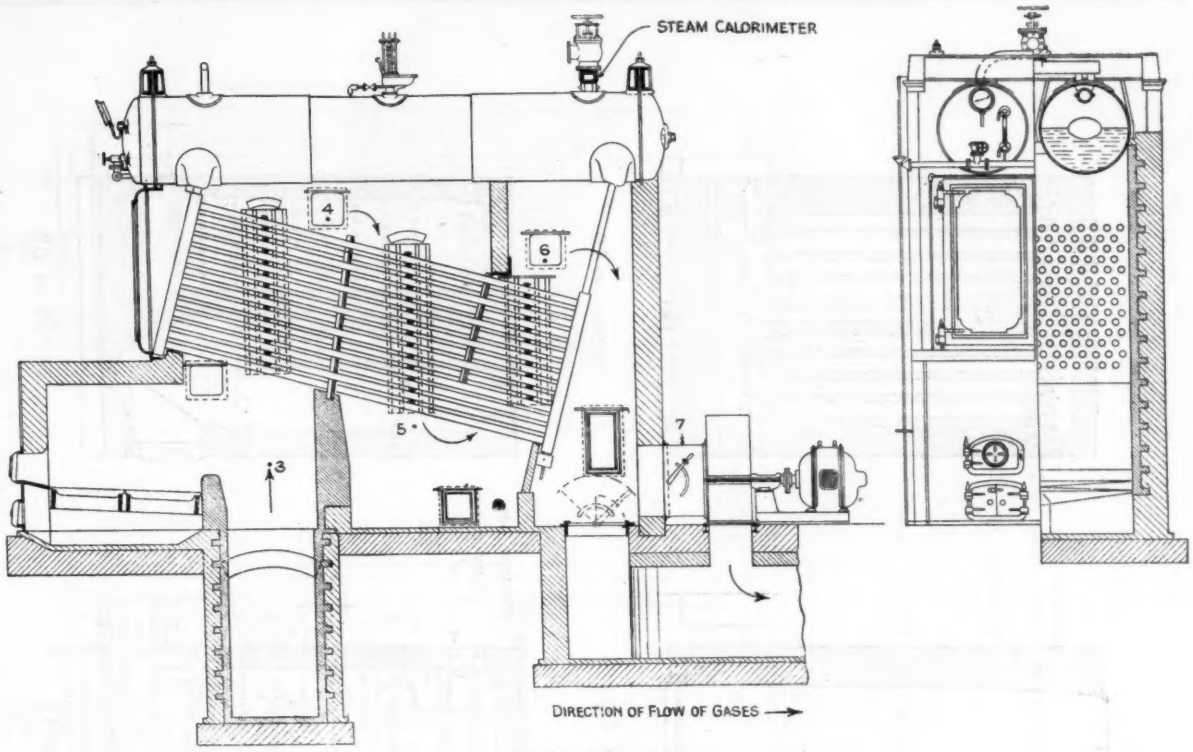


DIAGRAM III.

Babcock and Wilcox Waste Heat Boiler, Range D, at Windsor Street Gas-Works, Birmingham.

heater is 490 sq.ft. The drum is of such dimensions that a difference in water level of one inch about the middle of the gauge glass is equivalent to 54 gallons. The permissible working pressure is 140 lbs. per sq.in.; the hydraulic test at the time of the installation of the boiler was carried out at a pressure of 320 lbs. per sq.in. According to the last report (September, 1923) of the insurance inspector, the boiler was in good condition throughout. The quality of the feed water was described as good. The path of travel of the gases through the boiler is indicated in Diagram V. by means of arrows. It will be observed that the gases leave the boiler near the top, whereas, in the boiler attached to Range D, the gases leave at ground level. The boiler fittings are similar to those already mentioned for the boiler of Range D.

Mechanical Draught.—A Sirocco fan and 25 H.P. motor with direct coupling are situated on an elevated staging on a level with the gas outlet near the top of the boiler (Diagram VI.). The diameter of the circular inlet of the fan is 3 ft. 9 in., and the discharge outlet is 1 ft. 10 in. square. The motor is of the induction type with short-circuited rotor, and is designed for a speed of about 735 revolutions per minute with a current potential of 440 volts, 50 periods per second, and three-phase.

Chimneys, Range E.—The waste gases pass from the fan into a metal flue arranged as shown in Diagram VI. The gas is thus divided into two streams to enter the two chimneys. The only object in dividing the gas stream is to keep both chimneys warm, and thus reduce deterioration. Each chimney is 120 ft. high, 4 ft. diameter at the top, and 6 ft. diameter at the base.

PLANT ROUTINE.

The object of the investigation was to determine the amount of steam which could be raised in a waste-heat boiler attached to a typical installation of continuous vertical retorts, when both the retort installation and the boiler were being operated under the conditions of ordinary works practice. Throughout the tests described in this report, the usual routine of operation was therefore adopted. The retort feed hoppers were charged with coal from the main bunkers every two hours, and the coke was withdrawn from the chambers at the bottom of the retorts every two hours. The retorts were rodded every hour. The producer fires were cleaned and charged with coke every four hours.

Every boiler is ordinarily scaled every four months. The boiler attached to Range D was cleaned and scaled during October, 1923. The first complete test of this boiler was conducted during November, and the second test was run early in January, 1924. The boiler attached to Range E was cleaned during January, and the complete test was carried out early in February.

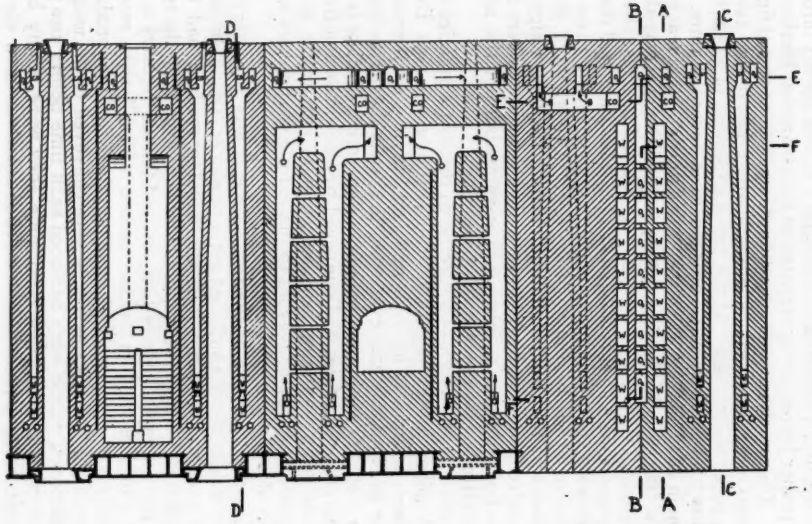
MEASUREMENTS AND WEIGHINGS.

Coal to Retorts.—The coal used during the tests was obtained from a number of collieries in the Yorkshire, Derbyshire, and Staffordshire coalfields; it was passed through a crusher before being elevated to the main coal bunkers.

The weight of coal carbonized is not an essential figure in tests of a waste-heat boiler installation, but it was taken as a point of interest. At the commencement of a test, the retort feed hoppers were charged at a recorded time. The main coal bunkers were then filled until the coal reached the guiding rails of the tray conveyors, and the coal was allowed to retain its angle of repose. At the end of a test the retort hoppers were again charged at a recorded time, and the main bunkers again filled to as nearly as possible the same position as at the beginning of the test. The whole of the coal used was weighed; and in calculating the total weight carbonized, the weight required to fill the main bunkers at the end of the test was taken into account, but not the amount required to fill them at the beginning.

Coke to Producers.—According to the usual practice at the Windsor Street Works of the Birmingham Gas Department, an amount of coke sufficient for the requirements of the producers is conveyed from the retort discharge hoppers to hoppers with bar screens. The screened coke is then charged into bogies and conveyed by electric locomotives to underground chutes, from which it is carried by gravity bucket and tray conveyors to the main coke bunkers at the top of the retort-house.

For the purpose of the tests, since it was necessary that the weight of coke supplied to the producers should be known as accurately as possible, the usual procedure had to be modified. The coke required was conveyed from the retorts direct to ferro-concrete hoppers, and thence to rotary screens of 2-in. mesh. Ten trucks marked "Test" were reserved solely for the screened coke required for the producers. From the screens the trucks were conveyed to the weighing machines, which were balanced each time before use; and the trucks were tared each time they were empty before again being loaded. The screened coke was then elevated by bucket and tray conveyors to the bunkers at the top of the retort-house. At the beginning of each test, the producers were fully charged, and the main coke bunkers were completely emptied at recorded times. The whole of the coke supplied was then weighed until the end of the test,



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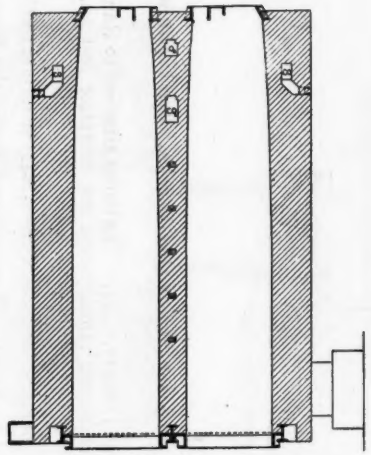

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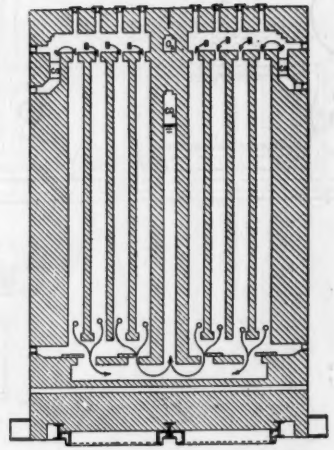

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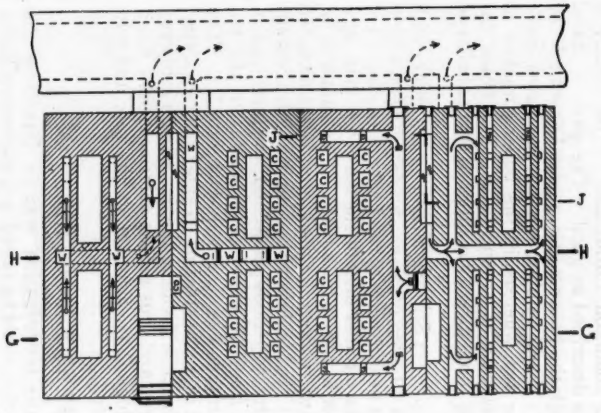

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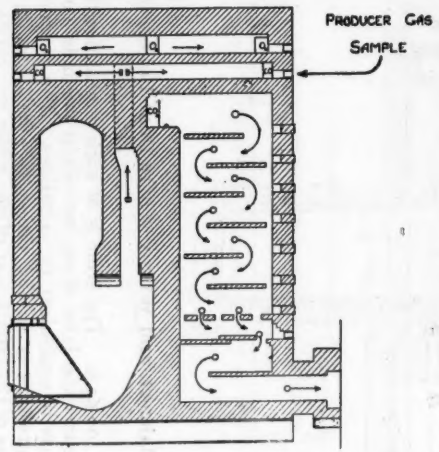

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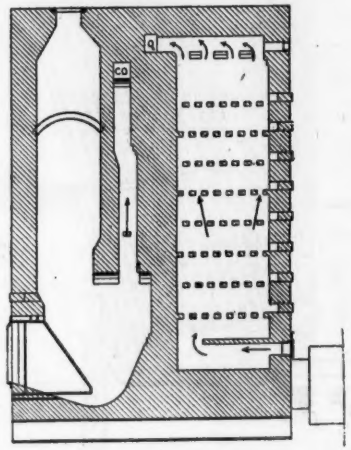
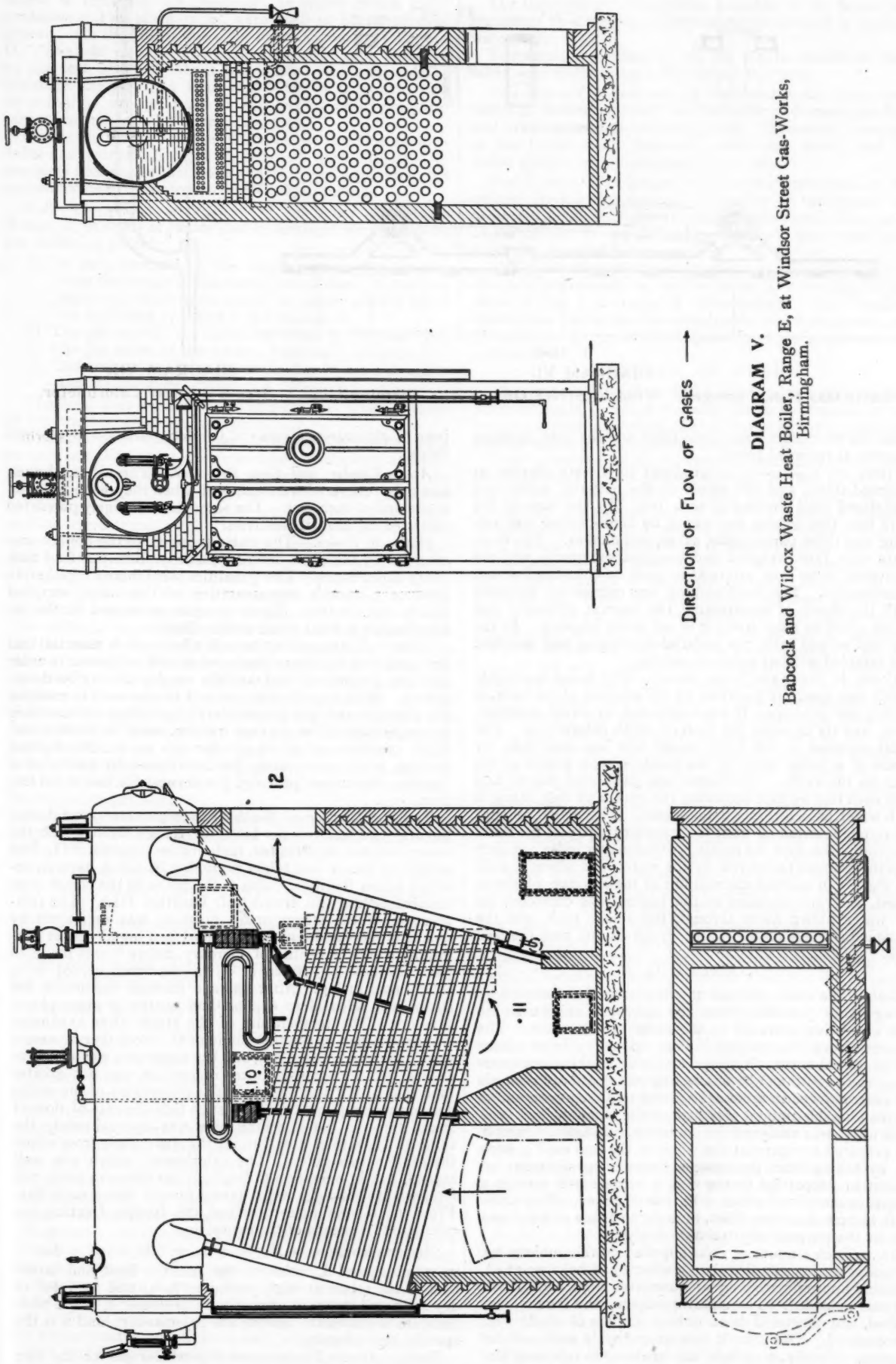


SECTION ON BB

Submitted to and approved by Messrs Woodall-Duckham Vertical Retort and Oven Construction Co (1920), Ltd



DIRECTION OF FLOW OF GASES ⟶

DIAGRAM V.

Babcock and Wilcox Waste Heat Boiler, Range E, at Windsor Street Gas-Works, Birmingham.

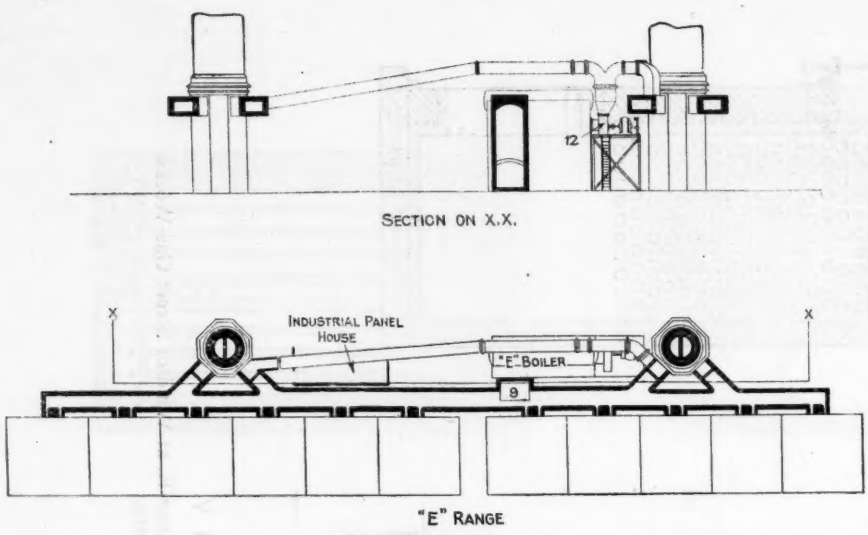


DIAGRAM VI.

Waste Gas Flues, Range E, Windsor Street Gas-Works, Birmingham.

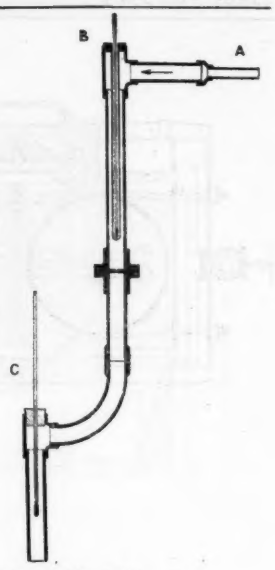


DIAGRAM VII.

Steam Dryness Calorimeter.

when the producers were again filled and the coke bunkers emptied at recorded times.

Ashes and Clinker.—The producer fires were cleaned at recorded times, and the whole of the material withdrawn was stored until the end of each test. In the case of the third test, this residue was sorted by hand-picking and riddling into three parts—coke, ashes, and clinker. The three parts were then weighed and sampled separately, and the recovered coke was afterwards used in coke-fired steam superheaters. The hand-picking was carried out specially with the object of ascertaining the amount of useful fuel which could be recovered; it is not usual practice. In the first and second tests the material withdrawn was weighed and sampled without previous sorting.

Water to Boiler and Steam Raised.—The boiler feed tank, which was specially installed for the purpose of the tests, is rectangular in shape; it was calibrated by direct measurement, and its capacity per inch of depth determined. The water supplied to the boiler under test was measured by means of a water meter of the positive type, placed at the inlet to the tank. The meter was calibrated before and after each test by first emptying the tank, and then filling it with water passed through the meter. The actual amount delivered, ascertained from the known capacity of the tank, was compared with the readings of the meter index; in each case the amount registered by the meter was about 1 p.ct. too high. In making calculations of the amounts of steam raised, the water supplied to the boilers was corrected for the water blown away through the sludge cock and the changes in levels of the water in the drums and the feed tank.

SAMPLING.

Coal.—The coal supplied to the retorts was sampled by taking small quantities from the conveyor buckets as the coal was being elevated to the main coal bunkers. The amounts were then mixed, broken up into smaller pieces and quartered down. The operations of crushing and quartering were continued on a sampling plate until each sample had been reduced in amount to about 1 lb. As soon as the sample for each amount elevated to the bunkers had been made up, it was analyzed for moisture. Finally, a sample was prepared to represent the whole of the coal used in each test, by taking from the sample for each consignment an amount in proportion to the weight represented, so that a composite sample of about 1 lb. was obtained. The composite sample was then dried, brought to a fine powder, and used for the purpose of proximate analysis.

Coke.—Each amount of coke supplied to the bunkers for the producers was sampled shortly after it had been weighed, by taking approximately equal quantities from each truck as it was unloaded. The quantities taken were then mixed, crushed, and quartered down until a sample of about 1 lb. was obtained. This sample was immediately analyzed for moisture. Finally, a sample was made up to represent the whole of the coke used in each test. The final sample for the test was brought to a fine powder and used for the purpose of ultimate analysis and the determination of calorific values.

Ashes, Clinker, and Coke Recovered.—The ashes, clinker, and coke recovered were sampled when they were weighed at the end of each test. The samples were finely powdered and used for ultimate analysis.

Water to Boiler.—The water supplied to the boilers was sampled by taking a definite quantity from the feed tank every eight hours. The quantities were mixed together, to produce a sample representative of the water supplied throughout the test. These samples were used for the determination of total solids and hardness.

Steam.—When making tests of a boiler, it is essential that the quality of the steam produced should be known, in order that the amount of heat usefully employed may be determined. With superheated steam it is necessary to measure the pressure and the temperature; but when the steam is not superheated, the dryness fraction must be ascertained. With pressures of about 130 lbs. per sq. in., the dryness fraction may conveniently be determined by means of a throttle calorimeter, provided the dryness fraction is not less than 0·95.

The construction of the throttle calorimeter used during the first two tests on the boiler of Range D, in which the steam was not superheated, is shown in Diagram VII. The sample of steam was taken through a half-inch pipe A, inserted below the main valve of the boiler in the steam pipe connecting the two drums (*vide* Diagram III.). The temperature of the steam under pressure was registered by means of the thermometer B, placed in a metal pocket containing a small quantity of mercury, before it was made to pass through an orifice of $\frac{1}{16}$ in. diameter drilled in a solid brass fitting. After passage through the orifice, the steam was allowed to expand and escape at atmospheric pressure. The temperature of the steam after expansion was determined by the thermometer C. Both thermometers were calibrated before use, and the apparatus was tested to ensure that the pressure after expansion was not greater than that of the atmosphere. The dimensions of the orifice and of the sampling pipe were such that the rate of flow of steam through the sampling pipe was approximately the same as the rate of flow through the steam main from which the sample was taken. The calorimeter, which was well lagged, was in operation throughout the first two tests, and temperature readings were taken several times each day. From the temperatures obtained, the dryness fraction was calculated by means of the expression

$$\text{dryness fraction} = [h_s - h_1 + L_s + S\,(t_2 - t_s)] \div L_1$$

in which h_1 and L_1 refer to the sensible heat and latent heat of the steam at high pressure; t_s, h_s, and L_s refer to dry saturated steam at atmospheric pressure; t_2 is the temperature of the steam leaving the calorimeter; and S is the specific heat of steam.

Producer Gas.—The samples of producer gas for the two tests on Range D were taken through silica tubes placed in four positions, of which two for one-half of the range are

indicated in Diagram II. Each sampling point represented the gas made in two producers, so that samples were obtained to represent the gases for the whole of the eight producers. The silica tubes were held in barrel nipples screwed into the lids of the sight holes shown in Diagram II. The total number of samples taken was approximately 55 per test, of which about one-fourth were subjected to complete analysis in a Bone and Wheeler apparatus, and three-fourths were analysed for carbon dioxide, oxygen, and carbon monoxide in an Orsat apparatus.

During the test on Range E, about 50 samples of producer gas were taken, of which one-half were subjected to complete analysis in the Bone and Wheeler apparatus, the remainder being examined in the Orsat apparatus.

Waste Gas.—During the tests of the boiler attached to Range D, samples of waste gas for analysis were taken at the following points:

(*a*) In both sections of the vertical down flue leading from the range to the underground flue. These two positions, which were 4 ft. 6 in. above ground level, are indicated by 1 and 2 in Diagram I.
(*b*) The gas inlet to the boiler—position 3, Diagram III.
(*c*) The gas outlet of the boiler—position 7, Diagram III.
(*d*) The underground flue between the by-pass dampers and the chimney—position 8, Diagram I.

The total number of samples of waste gas taken in each of the first two tests was approximately 75.

The amount of water vapour accompanying the waste gas at each sampling point was determined by drawing a stream of the gas through a train of apparatus arranged in the following order: (1) a bottle to catch any water condensed out by atmospheric cooling; (2) two wash-bottles each containing concentrated sulphuric acid; (3) a wash-bottle containing water; (4) an experimental gas-meter; (5) a bottle with a water seal device so arranged as to ensure a constant pull; and (6) a suction pump. The bottles (1) and (2) were weighed before and after each experiment, and the increase in weight represented the amount of water vapour. The weight of the second bottle of sulphuric acid was generally the same before and after each experiment, the water vapour having been almost completely removed before the gas reached this point. The wash-bottle (3) containing water was inserted for the purpose of saturating the gas before measurement in the meter. During a test, four determinations of water vapour were made at each sampling point, so that there were 16 determinations in all. Each determination covered a period of over 24 hours, and the rate at which the gas was passed through was approximately 1 c.ft. per hour.

During the third test on Range E, samples of waste gas were taken, and determinations of water vapour were made at the following points:

(*i*) In the down flue at the entrance to the boiler about 2 ft. 6 in. above ground level—position 9, Diagrams I. and VI.
(*ii*) The gas outlet of the boiler—position 12, Diagrams V. and VI.

The total number of samples of waste gas taken during this test was approximately 40.

MEASUREMENT OF TEMPERATURES, PRESSURES, &c.

Temperatures. — The temperatures of the combustion chambers round the retorts were measured by means of a Cambridge optical pyrometer.

The temperatures of the waste gases were measured by means of iron-constantan thermo-couples installed at all the points at which the waste gases were sampled—*i.e.*, at positions 1, 2, 8, and 9 of Diagram I.; 3 and 7 of Diagram III.; and position 12 of Diagrams V. and VI. In addition, the temperatures of the gases during passage through the boilers were taken at positions 4, 5, and 6 of Diagram III; and 10 and 11 of Diagram V. The thermo-junctions were directly exposed in the streams of gas; and the separate iron and constantan wires were insulated from one another by means of silica tubes. The thermo-couples were connected by iron-constantan cables to a switchboard which was in circuit with the galvanometer. The temperature of the galvanometer and switchboard, which were situated in a cool position, was indicated by a mercury thermometer, and the necessary corrections were applied.

The temperature of the superheated steam in the third test was indicated by a thermo-couple placed in a metal pocket in the steam pipe below the main boiler valve.

The temperature of the water supplied to the boiler was registered by a mercury thermometer suspended in the feed water tank.

Temperature readings at all the points mentioned were taken several times each day during the tests.

Pressures.—The pressures in inches of water gauge were taken at several positions in the boiler and waste-gas flues and in the retort gas-collecting main. Systematic readings of the boiler steam pressures were also taken, and the boiler gauges were calibrated before use.

Fan Motors.—The power, in kilowatts, consumed by the motors driving the fans at the outlets of the boilers was measured by a calibrated recording wattmeter. The speeds of the motors in revolutions per minute were also systematically recorded.

The calibration of the wattmeter was carried out against standard instruments in the Electrical Engineering Department of the University of Birmingham. The Research Committee wishes to acknowledge the facilities granted, and to thank Mr. Kipps, of that department, for his advice in this matter.

DETAILS OF TESTS.

The principal results of the three tests carried out are given in Table I., which includes the data obtained for the weights of coal carbonized, the fuel supplied to the producers, and the steam raised in the waste-heat boilers.

During the two or three weeks immediately preceding a test, each retort in the range had been scurfed, in the hope that it would be possible to have all the retorts at work throughout the selected test period of 120 hours. The retorts of Range D, which had been in operation without resetting for a period of five years, were in poor condition; and owing to the hanging-up of the charges, it was at times necessary in ordinary practice to empty retorts before the normal time for scurfing. When all preparations had been made for the first test, however, conditions turned out to be so favourable that the test was commenced with all retorts in operation; and two retorts only had to be let-down during the last two days of the test. By the time preparations had been completed for the second test, it was necessary to commence with five retorts out of action. These retorts were charged with coke and put into work as circumstances permitted; but as some retorts were set in operation, others had to be let-down, with the result that the average number operating during the test was only 26·5 out of a possible 32. The retorts of Range E were in good condition; no difficulty was experienced in carrying out the third test with all 44 retorts in action.

The weights of dry coke supplied to the producers, expressed as percentages of the weights of coal carbonized in the three tests, were respectively 13·3, 14·9, and 15·7 p.ct.; and the weights of material withdrawn from the producers were 2·7, 3·3, and 2·6 p.ct. of the weights of coal carbonized. The heat values of the fuel gasified in the producers per 100 lbs. of dry coal carbonized in Tests 1, 2, and 3 were respectively 1·52, 1·68, and 1·87 therms. Comparing Tests 1 and 2, the greater fuel consumption per 100 lbs. of coal in Test 2 was undoubtedly due to the fact that fuel was being consumed for the purpose of heating retorts which were out of operation. The highest figure of 1·87 therms in Test 3 is accounted for partly by the fact that in Range E difficulty was experienced in obtaining a sufficient supply of secondary air, with the result that the gases which left the combustion chambers contained more carbon monoxide than in either of the first two tests. Reference will be made again to this point in connection with the compositions of the waste gases.

As already mentioned, the material withdrawn from the producers during Test 3 was sorted by hand-picking and riddling into three parts—coke, ashes, and clinker, the respective dry weights of which for the complete test were 5·96, 18·72, and 3·43 tons, making the total weight of 28·1 tons given in Table I.

The amounts of water evaporated in the boilers during the three tests were equivalent to evaporations from and at 100° C. of 39·4, 42·5, and 53·4 lbs. per 100 lbs. of coal carbonized, or 2·97, 2·85, and 3·41 lbs. per lb. of coke supplied to the producers. The steam raised in Test 1 was 95·7 p.ct. dry, Test 2, 95·6 p.ct. dry, and in Test 3 the steam was superheated to 306° C.

Analysis of Coal, Coke, &c. (*Table II.*).—The results of

TABLE I.—*General Results of Tests.*

Test No.	1.	2.	3.
Duration of test, hours	120	120	120
Range	D	D	E
Retorts in range, total number	32	32	44
Rated capacity per retort per day, coal in tons	7	7	5
Retorts in operation, average number	31·6	26·5	44
Coal carbonized, dry weight, total in tons	1,064	896	1,078
Coal carbonized per retort per day, dry weight, tons	6·7	6·8	4·9
Fuel supplied to producers—			
Weight of coke as supplied, tons	145·7	140·1	175·0
Moisture content of coke, per cent.	3·0	4·6	3·5
Weight of coke, dry, tons	141·3	133·7	168·9
Weight of coke, dry, per 100 lbs. dry coal carbonized, lbs.	13·3	14·9	15·7
Calorific value (gross) of dry coke per lb., B.Th.U.	13,130	13,170	12,960
Heat value (gross) of coke per 100 lbs. dry coal carbonized, therms	1·74	1·96	2·03
Material removed from producers—			
Total weight, dry, tons	29·2	29·9	28·1
Weight per 100 lbs. dry coal carbonized, lbs.	2·7	3·3	2·6
Calorific value (gross) per lb., B.Th.U.	8,090	8,410	6,010
Heat value (gross) per 100 lbs. dry coal carbonized, therms	0·22	0·28	0·16
Heat value (gross) of fuel gasified in producers per 100 lbs. dry coal carbonized, therms	1·52	1·68	1·87
Waste-heat boilers—			
Weight of water supplied, lbs.	815,960	737,940	982,410
Temperature of water supplied, °C.	18	14	20
Weight of water blown-off, lbs.	5,070	4,730	480
Temperature of water blown-off, °C.	181	180	180
Weight of steam raised, lbs.	810,890	733,210	981,930
Gauge pressure of steam, lbs. per sq. inch	134	131	132
Temperature of steam, °C.	181	180	306
Quality of steam, dryness fraction	0·957	0·956	dry
Superheat, °C.	..	..	126
Equivalent evaporation from and at 100° C., total in lbs.	938,150	853,360	1,290,500
" " " " lbs. per hour	7,818	7,111	10,754
" " " " lbs. per 100 lbs. dry coal carbonized	39·4	42·5	53·4
" " " " lbs. per lb. dry coke supplied to producers	2·97	2·85	3·41

TABLE II.—*Analyses of Coal, Coke, Coke Recovered, Ashes, and Clinker.*

Test No.	1.	2.	3.		
Range	D	D	E		
Coal—					
Proximate analysis—					
Moisture	4·7	5·7	..		
Volatile matter	34·5	33·7	..		
Fixed carbon	54·5	54·0	..		
Ash	6·3	6·6	..		
	100·0	100·0			
Coke to producers—					
Ultimate analysis of dry samples—					
Ash	8·4	8·7	9·7		
Carbon	87·9	87·4	86·7		
Hydrogen	0·6	0·7	0·5		
Sulphur	1·6	1·6	1·6		
Nitrogen and oxygen (difference)	1·5	1·6	1·5		
	100·0	100·0	100·0		
Calorific value (gross) of dry coke in B.Th.U. per lb.	13,130	13,170	12,960		
			Coke Recovered.	Ashes.	Clinker.
Material removed from producers—					
Ultimate analysis of dry samples—					
Ash	44·1	41·7	26·1	62·3	92·8
Carbon	54·5	57·1	72·5	36·6	6·7
Hydrogen	0·2	0·1	0·2	0·1	0·0
Sulphur	0·9	1·1	1·2	1·0	0·5
Nitrogen and oxygen	0·3	0·0	0·0	0·0	0·0
	100·0	100·0	100·0	100·0	100·0
Calorific value (gross) of dry sample in B.Th.U. per lb.	8,090	8,410	10,720	5,420	990

proximate analysis of samples of the coal supplied to the retorts during the tests on Range D, together with ultimate analyses and calorific values of the fuel supplied to the producers and of the ashes, &c., withdrawn during all three tests are given in Table II. The time required to obtain the essential data in the test on Range E was such that the sampling of the coal—a point of minor importance in this investigation—had to be abandoned. The coal carbonized was a mixture from the same collieries as in the first two tests.

The calorific values of the coke supplied to the producers were determined in a Mahler-Kröcker bomb; but the calorific value of the ashes, &c., withdrawn have been calculated from the ultimate analyses by means of Dulong's formula. The coke recovered during Test 3 had a gross calorific value of 10,720 B.Th.U. per lb. (dry). Combining this figure with the weight recovered, 5·96 tons, it may be calculated that the heat value of the coke recovered was approximately 38 p.ct. of the heat value of the total material withdrawn, or about 3 p.ct. of the heat value of the coke supplied to the producers.

Temperatures, Pressures, &c. (*Table III.*).—The averages of the temperatures and pressures recorded at different points are given in Table III., which also includes the average speeds of the fans and the average amounts of power consumed by the fan motors. The points at which the temperatures and pressures of the waste gases were taken are indicated by references to positions numbered on several of the diagrams given in this report. In addition to the systematic readings, of which the averages appear in Table III., measurements were made of the temperatures of the waste gases leaving several of the combustion flues. The averages of these measurements were 970° C. for Test 1, 930° C. for Test 2, and 1020° C. for Test 3. A number of measurements of the temperatures of the waste gases during downward travel in Range E at points about 1 ft. above the entrances to the main waste-gas flue outside the range, gave the average figure of 930° C.

In the tests on Range D, it will be observed that there was a difference of approximately 135° C. in the temperatures taken in the vertical waste-gas flues (positions 1 and 2, Diagram I.), and those taken in the inlet to the boiler

TABLE III.—*Temperatures, Pressures, and Power Consumed by Fan Motor.*

Range.	Range D, Tests 1 and 2.				Range E, Test 3.		
	Position.		Test 1.	Test 2.	Position.		Test 3.
	Diagram No.	Position No.			Diagram No.	Position No.	
Temperatures in °C.—							
Waste-gas flues	I.	1 and 2	750	761	..	..	..
Inlet boiler	III.	3	611	631	I.	9	695
Within boiler	,,	4	425	442	V.	10	398
,, ,,	,,	5	339	357	,,	11	371
,, ,,	,,	6	309	324	..	..	..
Outlet boiler	,,	7	308	324	V.	12	269
Bye-pass damper	I.	8	283	277	..	..	..
Temperature combustion chambers, °C.			1285	1277			1336
Boiler feed water, °C.			18	14			20
Steam raised, °C.			181	180			306
Pressures, amounts below atmospheric, inches water gauge—							
Waste-gas flues	I.	1 and 2	0·9	0·9	..	..	..
Inlet boiler	..	..	..	..	I.	9	1 2
Outlet boiler	..	..	2·1	2·0	..	..	2·9
Chimney base	..	..	0·9	0·9	..	..	..
Retort gas collecting main	..	..	0 09	0·07	..	..	0·08
Speed of fan and motor, revs. per minute			740	670			740
Power consumed by fan motor, kilowatts			9·7	7 5			13·5
,, ,, ,, ,, horse power			13·0	10·1			18·1

TABLE IV.—*Analyses of Gases.*

Test No.	1.	2.	3.
Range	D	D	E
Composition of producer gas—volume per cent.: CO_2	7·4	8·1	6 6
O_2	0·2	0·1	0·1
CO	25·6	24·5	26·1
H_2	10·5	13·4	10·6
CH_4	0·3	0·3	0·5
N_2	56·0	53·6	56·1
	100·0	100·0	100·0
Calorific value in B.Th.U. per c.ft. (15·5° C. and 30 in. saturated) gross (calculated)	118	124	122
,, ,, ,, ,, ,, ,, net ,,	112	117	116
Compositions of waste gases—volume per cent.			
Waste-gas flues (positions 1 and 2, Diagram I.) CO_2	12·95	13·6	..
O_2	7·45	6·7	..
N_2	79·60	79·7	..
	100·00	100·0	..
Water vapour accompanying waste gas (positions 1 and 2, Diagram I.); lbs. per 1000 c.ft. (15·5° C. and 30 in. saturated)	4·21	4·71	..
Inlet boiler: CO_2	11·9	12·0	13·1
O_2	8·5	8·3	7·4
N_2	79·6	79·7	79·5
	100·0	100·0	100·0
Water vapour accompanying gas (inlet boiler); lbs. per 1000 c.ft. (15·5° C. and 30 in. saturated)	5·75	4·93	4·35
Outlet boiler: CO_2	11·3	11·2	10·3
O_2	9·2	9·2	10·4
N_2	79·5	79·6	79·3
	100·0	100·0	100·0
Water vapour accompanying gas (outlet boiler); lbs. per 1000 c.ft. (15·5° C. and 30 in. saturated)	5·49	4·64	3·53
Bye-pass damper (position 8, Diagram I.); CO_2	10·8	8·8	..
O_2	9·7	11·7	..
N_2	79·5	79·5	..
	100·0	100·0	..
Water vapour accompanying gas (bye-pass damper); lbs. per 1000 c.ft. (15·5° C. and 30 in. saturated)	5·26	3·76	..

(position 3, Diagram III.), although the amount of heat lost by radiation and convection over this distance could not have been more than a fraction of 1 p.ct. of the heat content of the gases entering the boiler. It will be proved later that this difference in temperature was caused mainly by leakages of air through the waste-gas flue brickwork, of water into the underground flue, and of waste-gas past the by-pass damper (position 8, Diagram I.).

The fan motors are designed to run at uniform speeds of approximately 740 revolutions per minute with the current available. The low speed of 670 revolutions per minute during Test 2 was achieved by inserting a temporary resistance in the rotor circuit. The resistance consisted of three metal plates suspended in a bath of dilute sodium carbonate solution; the bath was cooled by immersion in a larger tank provided with a supply of cold water and an overflow. The alteration in fan speed was made with the object of diminishing the suction in the waste gas flues and thereby reducing the leakages of air and waste gas already mentioned; it was believed that the fan power used during Test 1 was greater than was necessary. The true effect of the reduction in fan power in Test 2, however, was masked by the fact that fewer retorts were in operation and less fuel per day was gasified in the producers, with the result that a smaller volume of gas was passed through the boiler, and the pressure in the waste-gas flues remained about the same as in Test 1.

Compositions of Producer Gas and Waste Gas (Table IV.).—The average compositions of the samples of producer gas and of the waste gases taken at the positions indicated are shown in Table IV. The figures given as percentages of carbon dioxide were obtained by the usual method of absorption with sodium hydroxide, so that they include any sulphuretted hydrogen or sulphur dioxide which may have been present. From a number of experiments in which known volumes of the gases were passed through standard decinormal iodine solution, it was found that the amounts of iodine reduced were equivalent approximately to 0·17 p.ct.

by volume of sulphuretted hydrogen or sulphur dioxide in the producer gas, and 0·08 p.ct. by volume in the waste gas entering the boiler.

In addition to the analyses in Table IV., samples were taken at several points at which the gases left the combustion chambers to enter the waste-gas flues. The average amounts of carbon monoxide in the samples taken at these points were: 1·2 p.ct. in Test 1, 3·6 p.ct. in Test 2, and 4·6 p.ct. in Test 3. Samples taken during the downward travel of the waste gases in Range E, at positions about 1 ft. above the entrance to the horizontal waste-gas flue built outside the range, did not show any appreciable quantities of carbon monoxide, but contained an average amount of approximately 2 p.ct. of oxygen, so that air must have leaked into the waste gases during passage through the recuperators.

When it is considered that the amounts of carbon dioxide in the waste gases as they left the flues built within the ranges were of the order of 18 p.ct., it is at once realized that very large volumes of air must have leaked into the waste-gas flues to have caused reductions in the amounts of carbon dioxide to the percentages contained in the waste gases entering the boilers; and since the percentages of carbon dioxide had been further reduced by the time the gases left the boilers, air must also have entered the boiler settings. These leakages would have been even greater without the attention given to the brickwork of the flues and the boilers.

The amounts of water vapour which accompanied the waste gases at the different positions of sampling in all three tests are also included in Table IV. These amounts, expressed in pounds, represent the weights carried by those quantities of gases which would occupy 1000 c.ft if measured at 15·5° C. and 30 in. pressure and saturated with water vapour. During the first test the weight of water vapour carried with the gas in the vertical flues (positions 1 and 2, Diagram I.) was 4·21 lbs. per 1000 c.ft. At the inlet to the boiler, however, the amount had increased to 5·75 lbs., although the waste gas at this point had been diluted by leakages of air into the flues and of gas from the by-pass damper. This large increase in the amount of water vapour must have been caused by leakages of water into the underground flue. From an examination of the ground near the flue, it was found that an earthenware drainpipe was faulty. This defect was promptly remedied, and it will be observed from the figures for Test 2 that, although the leakage of water had not been entirely eliminated, it had been very considerably reduced.

Water to Boilers.—Samples representative of the water supplied to the boilers were examined for hardness and for the total amounts of dissolved solids. The results obtained are given in the following table, in which the amounts of hardness are expressed as parts of $CaCO_3$ per 100,000, and the total solids are expressed as parts per 100,000. Town water only was supplied during the first test, but in the second and third tests the supply consisted of mixtures from both sources.

TABLE A.

Test No.	1.	2.	3.
Temporary hardness	0·0	3·3	1·3
Permanent ,,	1·5	4·3	4·5
Total ,,	1·5	7·6	5·8
Dissolved solids	5·1	17·8	12·0

DEDUCTIONS FROM RESULTS.

The basic data obtained during the tests have been set out in Tables I. to IV., which have already been explained in the text. It now remains to arrange the results in such manner that they can conveniently be used for the purpose of deducing such fundamental facts as the quantities of gases dealt with, the amounts of various leakages, thermal efficiencies, &c. With these objects in view, the figures have been rearranged to represent quantities per hour.

Fuel to Producers (*Table V.*).—The weights and heat values of the fuel supplied to the producers and of the ashes, &c., withdrawn per hour are shown in Table V. The heat values and carbon contents of the fuel gasified per hour are also given. The figures against item (9) represent the volumes of producer gas of the compositions given in Table IV., equivalent to the weights of fuel gasified per hour.

Steam Raised in Boilers, &c. (*Table VI.*).—The first eight items of this table are self-explanatory. The figures against item (9), which represent the amounts of heat lost per hour by radiation and convection, were obtained by calculation of the rates at which heat would be transmitted through the brickwork, lagging, &c., of the boilers under the conditions of operation. In these calculations the thermal conductivities, in c.g.s. units, of the brickwork and asbestos lagging were assumed to be 0·001 and 0·0007 respectively. The skin temperatures at a number of points on the exposed surfaces were measured by placing the bulbs of mercury thermometers in small grooves made for the purpose. The bulbs were then covered with thin layers of asbestos lagging. When the lagging was quite dry, temperature readings were taken during several hours, and average figures for different parts of the boiler settings were obtained. The brickwork surfaces within the settings were considered to be at the same temperatures as the gases to which they were exposed; and the temperature of the surface of asbestos lagging in direct contact with the metal drums was taken to be the same as that

TABLE V.—*Fuel to Producers, Amounts per Hour.*

Test No.	1.	2.	3.
Range	D	D	E
(1) Weight of dry coke supplied to producers, lbs.	2,638	2,496	3,153
(2) ,, ,, material withdrawn from producers, lbs.	545	558	525
(3) ,, ,, carbon in coke supplied to producers, lbs.	2,318	2,181	2,733
(4) ,, ,, ,, ,, material withdrawn from producers, lbs.	297	319	213
(5) ,, ,, ,, gasified in producers, lbs. (item (3) *minus* item (4))	2,021	1,862	2,520
(6) Heat value (gross) of coke supplied to producers, therms	346·32	328·68	408·60
(7) ,, ,, ,, ,, material withdrawn from producers, therms	44·10	46·94	31·50
(8) ,, ,, ,, ,, fuel gasified in producers, therms (item (6) *minus* item (7))	302·22	281·74	377·10
(9) Volume of producer gas (reduced to 15·5° C., 30 ins. saturated), c.ft.	195,800	182,500	244,900

TABLE VI.—*Steam Raised in Boilers, Amounts per Hour.*

Test No.	1.	2.	3.
Range	D	D	E
(1) Weight of water supplied to boiler, lbs.	6,800	6,149	8,187
(2) ,, ,, blown off, lbs.	42	39	4
(3) ,, steam raised, lbs. (item (1) *minus* item (2))	6,758	6,110	8,183
(4) Equivalent evaporation from and at 100° C., lbs.	7,818	7,111	10,754
(5) Heat content of water supplied to boiler, therms	0·34	*minus* 0·18	0·73
(6) ,, ,, ,, blown off, therms	0·13	0·12	0·01
(7) ,, ,, steam raised, therms	76·23	68·85	105·12*
(8) ,, utilized in raising steam, therms (item (7) *minus* item (5))	75·89	69·03	104·39
(9) ,, lost from boiler by radiation and convection, therms	1·30	1·30	1·30
(10) ,, difference of gases (including water vapour) entering and leaving boiler, therms (sum of items (6), (8), and (9))	77·32	70·45	105·70

* This figure includes the heat utilized in superheating the steam.

of the steam raised. The amounts of heat lost from the metal doors and fittings were assumed to be the same per unit area as the amounts lost from the nearest brickwork possessing the same exposed surface temperature. Although the boiler setting of Range E is smaller than that of Range D, the calculated amounts of heat lost by radiation and convection per hour were approximately the same in all three tests. This is due to the fact that the boiler of Range D was not in operation during the third test, whereas both boilers were in operation during the first two tests; and these conditions influence the heat losses from the brickwork situated between the two boilers. The figure of 1 3 therms per hour for the amount of heat lost by radiation and convection is equivalent to less than 2 p.ct. of the heat value of the steam raised in any one of the tests, so that comparatively large errors in the assumptions made in deducing this figure would not be of any importance.

The sum of the heat supplied to the water blown-off from the boiler, the heat utilized in raising steam, and the heat lost by radiation and convection must be equal to the heat taken from the gases (including water vapour) during passage through the boiler; the results of these summations are given in item (10).

Gas Passed Through Boilers (*Table VII.*).—The relative volumes of the gases which entered and left the boilers may be calculated from the compositions given in Table IV. For example, in the case of Test 1, the gas at the inlet to the boiler contained 11·9 p.ct. carbon dioxide, and the gas at the outlet contained only 11·3 p.ct., the change in composition being due to leakages of air; so that if V represents the volume of gas which entered the boiler per hour, the volume at the outlet is given by $\frac{11\cdot9}{11\cdot3}$V—*i.e.*, 1·053V—and the amount of air leakage is represented by 0·053V.

By means of the data given in the Appendix to this report, the amount of heat carried by unit volume of gas and its accompanying water vapour at the inlet to the boiler may be calculated from the temperature given in Table III., the composition of the gas, and the amount of water vapour (Table IV.). The total amount of heat per hour carried by the waste gas and water vapour at the inlet to the boiler may then be expressed in terms of V. The amount of heat carried by the air which leaked into the boiler can also be determined in terms of V, provided values be assigned for the temperature and humidity of the air. In making actual calculations, it has been assumed that the air entered at 20° C., and that the quantity of air which, if measured at 15·5° C., 30 in. pressure and saturated, would occupy 1000 c.ft., was accompanied by 0·5 lb. of water vapour. The quantity of heat which entered the boiler is therefore given by the heat carried by the waste gas and water vapour *plus* the heat of the air and water vapour. The amount of heat carried by the gas and water vapour at the outlet of the boiler can also be expressed in terms of V; and since the difference in the heat value of the gases, including water vapour, which entered and left the boiler is equal to the quantity against item (10) of Table VI., a heat equation of the following type, with V as the only unknown quantity, may be constructed.

Heat of gas, air, and water vapour entering boiler *minus* heat of gas and water vapour leaving boiler } = item (10) of Table VI.

Equations of this type, constructed from the data procured during the three tests, have been solved, and the figures given against the first three items of Table VII. have been obtained. Simple calculations only are then required to deduce the values of the remaining items in Table VII.

The weights of water vapour in the gas at the inlets to the boilers appear in item (4), and the weights at the outlets in item (5), the differences in the two items being the amounts of water vapour carried by the air which leaked into the boilers.

Provided that the waste gases utilized in raising steam had resulted only from the combustion of producer gas and that no leakage had occurred, then the weights of carbon in the gas passed through the boilers—item (6), Table VII.—should have been approximately the same as the weights of carbon gasified in the producers—item (5), Table V. Comparing the two sets of figures, it is found that the amounts of carbon passed through the boilers exceeded the amounts gasified in the producers by about 300 lbs. per hour in each test. These differences in carbon weights must have been caused by leakages either of coal gas, &c., through the retort walls into the combustion flues, or of waste gas back again into the boilers from the chimney sides of the by-pass dampers, or by leakages from both sources.

TABLE B.

Test No.	1.	2.	3.
Carbon passed through boilers, lbs., item (6), Table VII.	2330	2180	2810
Carbon gasified in producers, lbs., item (5), Table V.	2021	1862	2520
Difference	309	318	290

TABLE VII.—*Gases Passed Through Boilers, Amounts per Hour.*

Test No.	1.	2	3
Range	D	D	E
(1) Volume of gas at inlet boiler (reduced to 15·5° C., 30 ins., saturated), c.ft.	631,800	588,200	694,500
(2) Volume of air leakage into boiler (,, ,, ,, ,,), ,,	33,500	41,800	188,900
(3) Volume of gas at outlet boiler (,, ,, ,, ,,), ,,	665,300	630,000	883,400
(4) Weight of water vapour in gas at inlet boiler, lbs.	3,630	2,900	3,020
(5) ,, ,, ,, ,, ,, ,, outlet boiler, lbs.	3,650	2,920	3,110
(6) ,, ,, carbon in gas passed through boiler, lbs.	2,330	2,180	2,810
(7) Heat content of gas and water vapour at inlet boiler, therms	191·80	175·71	221·32
(8) ,, ,, ,, ,, ,, ,, ,, outlet ,, ,,	114·48	105·26	115·62
(9) ,, difference of gas and water vapour at inlet and outlet boiler, therms	77·32	70·45	105·70

TABLE VIII.—*Heat Balances of Boilers, Therms per Hour.*

Test	1.	2.	3.
Range	D	D	E
(a) Heat value of waste gas, including water vapour, at inlet boiler	191·80	175·71	221 32
(1) Heat utilized in raising steam	75·89	69·03	91·48
(2) ,, ,, ,, superheating steam	..	..	12·91
(3) ,, supplied to water blown-off	0·13	0·12	0·01
(4) ,, lost by radiation and convection	1·30	1·30	1·30
(5) ,, value of waste gas, including water vapour, at outlet boiler	114·48	105·26	115·62
	191·80	175·71	221·32
(6) Heat value of steam required for power for fan motor (efficiency, 10 p.ct. on steam)	3·31	2·57	4·61
(7) ,, ,, ,, ,, ,, boiler feed pump (1 lb. of steam per 100 lbs. of water)	0·77	0·69	0·92
(8) Total heat value of steam required for auxiliary power	4·08	3·26	5·53
(9) Heat utilized in raising net weight of steam available	71·81	65·77	98·86
(10) Heat value of fuel supplied to producers	346·32	328·68	408·60
(11) ,, ,, ,, gasified in producers	302·22	281·74	377·10

The arrangement of the boiler setting and flues of Range D is such that from the data obtained during the first two tests it is possible to calculate the approximate amounts of the leakages of gas past the by-pass damper and of water into the underground flue. For the purpose of such calculations, it is necessary to construct carbon, water, and heat equations between the points of sampling in the vertical waste-gas flues (positions 1 and 2 of Diagram I.) and the inlet boiler. These equations may be constructed on the following principles:

Carbon Equation.—The amount of carbon per hour in the gas at the inlet boiler must be equal to the sum of the amounts of carbon in the gas at the vertical waste-gas flues and the carbon in the gas which leaked back again into the boiler past the by-pass damper.

Water Equation.—The weight of water vapour which entered the boiler per hour must be equal to the sum of the amounts of water vapour in the vertical waste-gas flues, the water vapour carried by the air leakage, the water vapour carried by the gas from the by-pass damper, and the water which leaked into the underground flue.

Heat Equation.—In the first instance the amount of heat lost by radiation and convection between the two positions under consideration was calculated from the thermal conductivity and skin temperatures of the brickwork; it was found that this heat loss was approximately 0·5 therm per hour. The heat per hour carried by the gas and water vapour at the inlet to the boiler *plus* 0·5 therm must therefore be equal to the sum of the heat contents of (*i.*) the gas and water vapour at the vertical waste-gas flues, (*ii.*) the air and water vapour which leaked into the flues between the two positions, (*iii.*) the gas and water vapour which travelled back from the by-pass damper, and (*iv.*) the water which entered the underground flue. In actual calculations, the initial temperature of this water was assumed to be 20° C.

From the data given in Tables I. to VII. and in the Appendix to this report, the three simultaneous equations for each test on Range D were constructed according to the principles outlined. The three unknown quantities (*a*) leakage of air, (*b*) leakage of gas past the by-pass damper, and (*c*) leakage of water into the underground flue, were then evaluated by solving each set of three equations. As a result of these calculations, it was found that the average amounts of the leakages per hour during the two tests on the boiler of Range D were as given in the following table:

TABLE C.—*Leakages per hour between Vertical Waste-Gas Flues and Inlet Boiler.*

Test No.	1.	2.
Volumes reduced to 15·5° C., 30 in. saturated—		
Air, c.ft.	45,000	42,000
Gas past by-pass dampers, c.ft.	37,000	79,000
Water into underground flue, lbs.	1,100	380

It has already been mentioned in the discussion of the figures in Table IV. that, after the completion of Test 1, an examination of the area near the underground flue revealed a faulty drainpipe, which was remedied before the commencement of the second test. Presumably this accounts for the large difference in the leakages of water during the two tests. The nature of the ground, in which the flue is situated, is such that infiltration of water—apart from that due to defects of the type mentioned—would not be surprising. Since the completion of this investigation, Range D has been shut-down, in preparation for the resetting of the retorts. The opportunity has therefore been taken to make an internal examination of the flues. This examination undoubtedly confirmed the fact that water had penetrated the underground flues near the inlet to the boiler, for the material deposited from the gases was not in the finely-divided condition in which flue dust is usually found, but was fritted together so that it could be removed in large pieces. Further, the uneven nature of the deposit suggested that the water had forced its way through crevices in different parts of the brickwork floor.

The amounts of gas which had already been through the boilers and which leaked back again past the by-pass dampers (Table C) appear at first sight to be remarkably large, and the difference in the volumes for the two tests seems to be even more remarkable. An examination of the dampers from the inside of the flue was therefore made and measurements were taken. Each damper (which consists of a metal plate 7 ft. by 2 ft. $5\frac{3}{4}$ in. by $3\frac{5}{8}$ in.) slides into metal grooves set in brickwork. These grooves are 5 in. in width—*i.e.*, $1\frac{5}{8}$ in. more than the thickness of the plates; and the distance between the grooves is 2 ft. $7\frac{1}{4}$ in.—*i.e.*, $1\frac{3}{4}$ in. more than the width of the plates. It can readily be calculated from these dimensions that the spaces available for the free passage of gas might easily be equivalent to a total area of more than 1 sq.ft. for the two damper plates. The actual area would vary considerably according to the exact positions of the damper plates, so that differences of the magnitude found in the two tests might easily be obtained. In connection with these leakages of gas, it should be pointed out that they do not exert so much influence on the performance of the boiler as leakages of the same volumes of air, since air enters at ordinary temperature and leaves at the temperature of the gas at the outlet of the boiler, whereas the gas which travels back past the by-pass dampers enters the boiler again at a temperature not very much lower than that at which it leaves the boiler (*vide* Table III.).

It will be remembered from Table B, given in the text, that the weights of carbon in the gas passed through the boilers per hour exceeded the carbon gasified in the producers by 309 lbs. and 318 lbs. in Tests 1 and 2 respectively. From the compositions given in Table IV. and the volumes in Table C, it may be calculated that the amount of gas which leaked back past the by-pass dampers accounted in Test 1 for approximately one-third of the 309 lbs. difference in carbon weight; the remaining two-thirds being accounted for by leakages of coal gas, &c., through the retort walls into the combustion flues. This increase in carbon from coal gas, &c., really represents the excess of carbon passing from the retorts into the combustion flues over the carbon content of any waste gas which travelled in the opposite direction to enter the retorts. In the case of Test 2, leakage of gas from the by-pass dampers accounts for about two-thirds of the carbon difference of 318 lbs., the remaining one-third being accounted for by coal gas, &c.

These leakages of carbon through the retort walls may appear to be large, but it must be remembered that the retorts had been in operation for a period of five years. The leakages are also confirmed by comparison of the compositions of the producer gases and the waste gases. If no leakage from the retorts occurred, then the waste gas which would be obtained on combustion of the producer gas with the exact quantity of air should agree with the composition of the waste gas actually obtained and corrected for excess air. In the case of Test 1, however, the producer gas alone would give a waste gas containing 20·8 p.ct. carbon dioxide, whereas after removal of excess air the waste gas obtained would contain only 20·0 p.ct. carbon dioxide. Similarly in Test 2, the percentage of carbon dioxide in the waste gas from producer gas alone would be 20·4, as against 19·8 p.ct. in the waste gas corrected for excess air. Further, an examination of the retorts since the range has been out of operation has revealed the existence of holes in the retort walls.

The waste-gas flues of Range E are so arranged that it is not possible to calculate the volumes of the gases which leaked back into the boiler from the by-pass dampers, by the method adopted for Range D. In the first place, there are four separate branch flues to the two chimneys (*vide* Diagram I.). Each branch flue has a separate damper; and experiments have proved that the waste gases near these four dampers are at different temperatures and of different compositions. There are, therefore, more unknown quantities than could be evaluated from the number of equations it would be possible to construct. The retorts of Range E, however, were reset early in 1923, so that serious leakages through the retort walls would not be anticipated. This is supported by the fact that combustion of the producer gas with the theoretical quantity of air would yield a waste gas containing 20·4 p.ct. carbon dioxide, as against 20·3 p.ct. in the waste gas actually obtained, the necessary correction being made for the quantity of excess air. These two percentages differ by an amount which is smaller than the possible experimental error. It may, therefore, be concluded that in Test 3 the difference of 290 lbs. in the weight of carbon passed through the boiler and the weight gasified in the producers per hour is to be accounted for by leakages of gas from the by-pass dampers back into the boiler.

HEAT BALANCES AND THERMAL EFFICIENCIES OF BOILERS.

The heat balances of the boiler installations for the three tests are set out in Table VIII., in which the different items

are given in therms per hour. The amount of heat—item (a)—carried by the waste gas at the point at which it entered the boiler is taken from item (7) of Table VII. The expenditure of this amount of heat is accounted for in five items:

(1) Heat utilized in raising steam.—The figures for Tests 1 and 2 are taken from item (8) of Table VI. The value given for Test 3 is calculated on the assumption that the boiler alone, without the integral superheater, would have raised steam of a dryness fraction of 0·956.

(2) Heat utilized in superheating steam.—This item applies only to Test 3, since the steam raised was not superheated during the first two tests. The figure given is the difference between the heat utilized in raising and superheating the steam—item (8) of Table VI.—and the heat utilized in raising steam only—item (1) above.

(3) Heat supplied to water blown-off from boilers.—These values are taken from item (6) of Table VI.

(4) Heat lost by radiation and convection from the boiler settings.—This amount was deduced by the method already described in the explanation of Table VI.

(5) The heat carried by the waste gas at the point at which it left the boiler.—These amounts are taken rom item (8) of Table VII.

The following items in addition to those of the heat balance are also given in Table VIII.

(6) Heat value of steam required for power for fan motor. The values have been calculated on the basis of a 10 p.ct. thermal efficiency of power generation from steam—*i.e.*, on the assumption that the heat equivalent of the power consumed by the motor was 10 p.ct. of the heat value of the steam used in the turbine.

(7) Heat value of steam required for boiler feed pump. These figures have been calculated on the assumption that 1 lb. of the steam raised in the boiler would generate sufficient power to pump 100 lbs. of feed water under the conditions of the tests.

(8) Heat value of steam required for auxiliary power. These amounts have been obtained by the addition of items (6) and (7).

(9) Heat utilized in raising net weight of steam available from the boilers. These values have been obtained by deducting item (8) from the sum of items (1) and (2).

(10) and (11) These values are taken from Table V.

In the balances in Table IX., the value of the heat content of the gases and water vapour at the inlet to the boiler is taken as 100, and the figures in items (1) to (9) are in proportion, so that they appear as percentages of the heat of the gases entering the boilers. The figures in item (1) represent the amounts of heat utilized in raising steam, as percentages of the heat available in the gases at the inlet to the boilers; and the percentage utilized in superheating the steam of Test 3 is shown in item (2). The first item therefore gives the gross thermal efficiencies of the boiler of Range D, and the sum of items (1) and (2) represents the gross efficiency of the boiler of Range E. The percentages of heat utilized in producing the net weights of steam available, after making the necessary allowances for the steam required for auxiliary power, are given in item (9), from which it may be seen that the net thermal efficiency of the boiler attached to Range D was 37·4 p.ct., and the net efficiency of the boiler and superheater attached to Range E was 44·7 p.ct. These efficiencies apply only to the conditions of operation during the investigation described in this report. They do not necessarily apply to other conditions, but they do represent the results obtainable in ordinary practice.

The amounts of heat required for the generation of auxiliary power averaged 2·2 p.ct.—item (8)—of the heat entering the boilers, or 5·1 p.ct.—item (12)—of the heat utilized in raising and superheating steam.

The quantities of heat utilized in raising the net weights of steam available—*i.e.*, after making allowances for auxiliary power—are expressed in item (10) as percentages of the heat values of the fuel supplied to the producers. These figures show that the proportions of heat recovered in this manner were 20·7 p.ct. in Test 1, 20·0 p.ct. in Test 2, and 24·2 p.ct. in Test 3. In the absence of waste-heat boilers, it would have been necessary to raise the same amounts of steam in boilers fired with solid fuel. On the basis of an efficiency of 70 p.ct., the solid fuel boilers would have consumed 8·6 tons of coke per day in Test 1, 8·0 tons in Test 2, and 12·1 tons in Test 3; the qualities of coke being the same as supplied to the producers. These weights, therefore, represent the amounts of solid-fuel saved per day by the waste-heat boilers, apart from a reduction in labour charges, since one boilerman per shift, in addition to other duties, is able to take charge of the six waste-heat boilers in the retort-house at Windsor Street.

Efficiencies of Gas Production.—According to the method recommended in the Clerk-Smithells-Cobb report to the Institution of Gas Engineers (April, 1919), and adopted in previous reports of this Committee (*vide* Fourth Report on Steaming in Continuous Vertical Retorts), the efficiency of gas production in a retort-setting is determined from the expression,

$$\frac{\text{Heat value of gas made}}{\text{(Heat value of gas made) } \textit{plus} \text{ (heat used and lost)}} \times 100 \quad . \quad . \quad \text{(A)}$$

The heat used and lost is made up of the heat of the fuel supplied to the producers, the heat required for raising the steam supplied to the retorts, and the heat lost, as determined from a thermal balance. The production of steam in waste-heat boilers of the type used in this investigation in place of separate boilers would, therefore, cause an increase in the thermal efficiencies of gas production. The approximate amounts of the resulting increases in efficiency may be determined in the following manner. If the efficiency of gas production according to the method adopted in the Fourth Report (with solid fuel boilers) were 60 p ct., then expression (A) could be put in the form,

$$\frac{60}{(60) + (30 + 10)} \times 100 = 60 \text{ p.ct.}$$

in which 40 represents the heat used and lost in manufac-

TABLE IX.—*Heat Balances of Boilers, Per Cent.*

Heat value of waste gas and water vapour at inlet boiler = 100.

Test No.	1.	2.	3.
Range	D	D	E
(1) Heat utilized in raising steam	39·57	39·29	41·34
(2) ,, ,, ,, superheating steam	..	..	5·83
(3) ,, supplied to water blown-off	0·07	0·07	0·00
(4) ,, lost by radiation and convection	0·68	0·74	0·59
(5) ,, value of waste gas, including water vapour, at outlet boiler	59·68	59·90	52·24
	100·00	100·00	100·00
(6) Heat of steam required for power for fan motor (efficiency 10 p.ct. on steam)	1·73	1·47	2·08
(7) ,, ,, ,, ,, ,, boiler feed pump (1 lb. of steam per 100 lbs. water)	0·40	0·39	0·42
(8) Total heat value of steam required for auxiliary power	2 13	1·86	2·50
(9) Heat utilized in raising net weight of steam available, *i.e.*, net efficiency of boiler	37·44	37·43	44·67
(10) Heat utilized in raising net weight of steam, expressed as p.ct. of fuel to producers	20·7	20·0	24·2
(11) Heat utilized in raising net weight of steam, expressed as p.ct. of fuel gasified	23·8	23·3	26·2
(12) ,, of steam for auxiliary power, expressed as p.ct. of heat utilized in raising and superheating steam	5·4	4·7	5·3

TABLE X.—*Supplementary Data.*

Test No.	1.	2.	3.
Range	D	D	E
(1) Area of heating surface of boiler, sq. ft.	4315	4315	3176
(2) ,, ,, ,, superheater, sq. ft.	..	..	490
(3) Heat utilized in raising steam per sq. ft. heating surface per hour, boiler, B.Th.U.	1759	1600	2880
(4) ,, ,, superheating steam per sq. ft. heating surface per hour, superheater, B.Th.U.	..	..	2635
(5) Equivalent evaporation, from and at 100° C., per sq. ft. heating surface per hour, lbs.	1·81	1·65	2·93

ture. This figure of 40 is subdivided into 30 for the heat used and 10 for the heat lost, as representative of average practice with continuous vertical retorts.

During Test 1 of this Report, the amount of fuel saved by the waste-heat boiler was equivalent to 20·7 × 100 ÷ 70 *i.e*, 29·6 p.ct. of the fuel used in the producers. The efficiency of gas production would therefore become

$$\frac{60}{(60) + (10) + \left(\frac{100 - 29{\cdot}6}{100}\right) \times 30} = \frac{60}{91{\cdot}1} = 65{\cdot}9 \text{ p.ct.}$$

The waste-heat boiler installation therefore resulted in an increase in the efficiency of gas production of 5·9 p.ct., on the assumption that the efficiency without waste-heat boiler was 60 p.ct. By the same method of calculation it can be shown that the waste-heat boilers accounted for increases in the efficiencies of gas production of 5·6 p.ct. in Test 2, and 7·0 p.ct. in Test 3. It may thus be concluded that the production of steam by means of waste-heat boilers attached to vertical-retort installations, operated as described, results in an increase in the efficiency of gas production of approximately 6 p.ct.

Leakages of Air.—The thermal efficiencies of the waste-heat boilers used during the tests described could undoubtedly be improved by adopting measures to prevent the large leakages of air into the waste-gas flues and the boiler settings. With ordinary regulation of the retort-settings, the waste gases should contain approximately 18 p.ct. of carbon dioxide at the points at which they enter the waste-gas collecting flues. The average amounts of carbon dioxide in the waste gases at the outlets of the boilers were, however, only 11·3 p.ct., 11·2 p.ct., and 10·3 p.ct. respectively in the three tests. If it be assumed that, with no leakages of air, the waste gases leaving the boilers would contain 18 p.ct. carbon dioxide, then the volumes of air which must have entered the flues and boilers can be calculated from the compositions given in Table IV. and the volumes of gases given in Table VII. Calculations of this nature show that dilutions from 18 p.ct. carbon dioxide must have been brought about by leakages of 248,000 c.ft. of air per hour in Test 1, 238,000 c.ft. in Test 2, and 378,000 c.ft. in Test 3. These volumes of air, at the temperatures at which they left the boilers, must have carried amounts of heat of 23·6 therms per hour in Test 1, 23·9 therms in Test 2, and 31·0 therms in Test 3. These amounts of heat expressed as percentages of the heat values of the gas at the inlet to the boiler are 12·3 p.ct., 13·6 p.ct., and 14·0 p.ct. respectively in the three tests. If the leakages of air were eliminated, the whole of these amounts of heat would not necessarily be utilized in raising steam, but large proportions would be recovered, with resulting improvements in the efficiencies of the boilers. The prevention or reduction of air leakage by the use of tongued and grooved bricks or brick-lined metal flues, or by other means, is, therefore, worthy of serious consideration.

SUPPLEMENTARY DATA.

It is useful when making comparisons of different waste-heat boilers to know the amounts of heat utilized in raising steam per sq.ft. of heating surface per hour, provided that in making such comparisons the different conditions of operation are also considered. Supplementary data of this nature are therefore given in Table X.

APPENDIX.

DATA EMPLOYED IN CALCULATIONS.

The values given below have been employed in the calculations made in the preparation of the tables in this report.

HEAT CAPACITIES IN B.TH.U. PER C.FT.

(15·5° C. and 30 in. satd.).

Heat capacity of water vapour in gas not included.

t = temp. ° C. *minus* 15·5.

N_2	$0{\cdot}032t + 0{\cdot}0000187t^2$
O_2 and CO	$0{\cdot}0322t + 0{\cdot}0000234t^2$
CO_2	$0{\cdot}0418t + 0{\cdot}0000117t^2$

HEAT CAPACITIES IN B.TH.U. PER POUND:

t_{100} = temp. ° C. *minus* 100.

H_2O (vapour) . $0{\cdot}915t_{100} + 0{\cdot}000215t^2_{100} + 1116$

CALORIFIC VALUES OF GASES IN B.TH.U. PER CUBIC FOOT

(15·5° C. and 30 in. satd.).

Gas.	CO.	H_2.	CH_4
Gross	318	320	992
Net	318	269	890

Calorific values of ashes and clinker (B.Th.U. per lb. gross). Dulong's formula.

$$[14{,}544\,C + 62{,}028\,(H - \tfrac{O}{8}) + 4050\,S] \div 100$$

in which C = carbon p.ct., H = hydrogen p.ct., O = oxygen p.ct., and S = sulphur p.ct.

DRYNESS FRACTION OF STEAM.

Example of calculation from expression.

Dryness fraction = $[h_3 - h_1 + L_3 + S\,(t_2 - t_3)] \div L_1$ in which h_1 and L_1 refer to the sensible heat and latent heat of the steam at high pressure, t_3, h_3 and L_3 refer to dry saturated steam at atmospheric pressure; t_2 is the temperature of the steam leaving the calorimeter, and S is the specific heat of steam.

Test 1. *Observed Readings.*

Average barometric pressure = 29·15 in. Hg. = 14·3 lbs. per sq. in.

Average temperature steam before expansion = 353·3° Fahr.

Average temperature steam after expansion, t_2 = 221·4° Fahr.

Substituting corresponding data from steam tables,

Dryness fraction = [178·0 − 325·0 + 971·7 + 0·48 (221·4 − 210·7)] ÷ 867·3.

= 829·8 ÷ 867·3

= 0·957.

Prof. COBB, in introducing the report, said: The results set out in this Twelfth Report have been obtained by Dr. Parker and his assistants, Mr. Kerr and Dr. Monkhouse, in investigating the performance of waste-heat boilers attached to settings of Woodall-Duckham continuous vertical retorts at the Windsor Street Works of the Birmingham Corporation Gas Department. A similar investigation was carried through two years ago on a waste-heat boiler attached to a carburetted water-gas plant, and the results were published in the Seventh Report of the Gas Investigation Committee. Having ascertained quantitatively the degree of economy effected in one case, it was plainly advisable to obtain figures for the other. If I pass at once to the results obtained, set out in the Summary and Introduction at the beginning of the report, it will be seen that the amounts of heat recovered in the waste-heat boilers in this investigation would bring up the efficiencies of gas production in normal working with continuous vertical retorts by about 6 p.ct.—*e.g.*, from 60 to 66 p.ct. It is plainly necessary to state such a result with reference to normal

working, because if the setting were worked abnormally with high temperatures in the waste gases, it would be possible to get much higher results for the evaporation and its effect on thermal efficiency. In order to obtain results which would be of real value to the industry, it was found necessary to bring into this study far more than the consideration of what the boilers would operate, and to obtain a large number of data for the working of different parts of the plant, beginning with the producers. Even when the gases had left the setting, certain factors operated, which had to be taken into account, or otherwise the results would have been misleading. These came in from such causes as the evaporation of water which was making its way into the main flue, and from the leakage of a by-pass damper which led to the re-circulation of some of the flue gases through the boiler.

Dr. Parker has gone into these things with his usual thoroughness, and the results are set out in the text of the report, and in the accompanying tables. So far as the waste-heat boilers and their performance are concerned, the results of three tests are summarized towards the end of the Introduction. Roughly speaking, the boilers were working with an efficiency of 40 p.ct., evaporating 40 lbs. of water per 100 lbs. of coal carbonized, or 3 lbs. of water per pound of coke to the producers. The low temperature head available in the boiler is, of course, responsible for the lowness of the efficiency figure as compared with direct firing.

Analyses have been made of the coal, coke, ashes, and clinker, of the producer gas, and of the waste gases resulting from its combustion in the setting. The quantities of gas passed through the boilers have been estimated, and heat balances have also been constructed, so that the whole process from the producer to the chimney can be followed through in its thermal and chemical detail. This analysis of the working of a vertical-retort installation with waste-heat boilers, and similar studies of steaming in vertical gas-retorts at Uddingston, of blue water-gas plant, and of the carburetted water-gas plant with waste-heat boilers at Birmingham may all be taken together as the working out of a scheme for arriving at the real position from the thermal and chemical standpoint of plant employed in the gas industry; and I question whether the work has ever been so thoroughly done before for any industry. It should prove of great service, and reflects very great credit upon Dr. Parker, who has been the man on the spot immediately responsible for obtaining and analyzing the results in every case. The Committee would like to thank him, not forgetting the members of his staff who have worked so loyally with him.

At the same time, the opportunity may be taken of expressing once more our sense of obligation to the Birmingham Corporation Gas Department, their General Manager (Mr. A. W. Smith), Mr. J. Foster (the Chief Engineer), Mr. T. F. E. Rhead (the Chief Chemist), Mr. G. A. Bamber, and Mr. G. C. Pearson, who have given us invaluable facilities and help in so much of our work during the past few years. It is all the more fitting that we should do this because for the time being, at any rate, our work at Birmingham has ended. Dr. Parker and his staff have now come to Leeds, in order to start work on the new experimental gas plant. This has been placed in the University of Leeds by Mr. Henry Woodall, with the co-operation of friends who wished to be associated with him, as a memorial of the late Sir Corbet Woodall, and it is hoped will prove of great service to the gas industry in enabling investigations to be carried out which for different reasons are unsuitable either for a laboratory or a full-scale plant. Dr. Parker is prepared to give a summary of the Twelfth Report.

Dr. A. PARKER (Research Chemist) then summarized the report:

The work described in this Twelfth Report constitutes a further step in the general inquiry into the thermal and chemical efficiencies of manufacture of different grades of gas. The inquiry was commenced by an investigation of the process of steaming the charges in the retorts of the Glover-West continuous vertical installation at the works of the Bothwell and Uddingston Gas Company. The results of the Uddingston tests, which appear in the Fourth Report, proved that, with proper control of the conditions, advantages are to be gained by moderate steaming. It was found that the thermal efficiency of gas production rose from 54 p.ct. without steam to a maximum of 62 p.ct. with steam. During these tests, the steam was raised in a separate boiler, which was assumed to have an efficiency of 70 p.ct. It was afterwards shown by calculation that, if the steam used in the retorts could have been raised in waste-heat boilers, the thermal efficiency of gas production would have been increased from 62 p.ct. to approximately 68 p.ct.—*i.e.*, by about 6 p.ct. The next step in the investigation, described in the Sixth Report, was carried out at the Adderley Street Works of the Birmingham Gas Department, with the object of determining the efficiency of production of blue water gas as ordinarily practised in a plant without waste-heat boiler. It was found that, taking into account the steam required for the generator and turbo-blower, the efficiency of gas production averaged 46 p.ct., and it was calculated that, if the steam required had been raised by means of a waste-heat boiler, the efficiency of 46 p.ct. would have been increased to 56 p.ct. This conclusion was supported by the results given in the Seventh Report, which describes an investigation of the manufacture of carburetted water gas in a Humphreys and Glasgow plant with attached waste-heat boilers. The amount of water evaporated in the waste-heat boilers was sufficient to supply the steam required for the generators, turbo-blower, and auxiliary plant, under the conditions of the tests.

It was pointed out in the Sixth Report that an alternative method of diminishing the loss of heat due to the potential heat of the blast gases in the manufacture of blue water gas might be to reduce the amount of carbon monoxide carried away up the stack, by changes in the method of operation of the plant, in so far as such changes could be made without prejudice to the efficient production of water gas during the run periods. This problem was investigated at the Adderley Street Works of the Birmingham Gas Department, and the results obtained are described in the Tenth Report. It was finally concluded that the manufacture of blue water gas by the intermittent process can be carried out more efficiently and with a greater output of gas per day when the ratio of carbon dioxide to carbon monoxide in the blow gas is about 0·9 than when this ratio is greater than unity. In other words, the amount of carbon monoxide in the blow gas should be rather more than the amount of carbon dioxide. From calculations of the heat available for use in a waste-heat boiler, it was also concluded that, even with the installation of a waste-heat boiler, the intermittent process would be more efficient under such conditions that the blow gas contained rather more carbon monoxide than carbon dioxide.

It will be appreciated from this brief account of the work on the manufacture of different grades of gas, described in the reports previously issued by the Research Committee, that the inquiry would not be complete unless it included an investigation of the heat recoverable in a waste-heat boiler attached to an installation of continuous vertical retorts. The Research Committee was therefore pleased to accept the generous offer of the Birmingham Gas Department to grant the necessary facilities and to allow an investigation to be conducted on the water-tube waste-heat boilers attached to the installations of Woodall-Duckham continuous vertical retorts at their Windsor Street Works. The method of conducting the investigation and the results obtained are described in this Twelfth Report. Since the object was to determine the amount of steam which could be raised in a waste-heat boiler attached to a typical installation of continuous vertical retorts, when both the retorts and the boiler were being operated under ordinary works practice, the usual routine of operation was adopted throughout the investigation.

The coal carbonizing installation at the Windsor Street Works consists of six separate ranges, designated A, B, C, D, E, and F of Woodall-Duckham continuous vertical retorts. With the exception of range D, each is made up of eleven settings of four 5-ton retorts. Each setting has a separate producer, a main coal bunker, and a coke bunker, so that a complete range includes eleven producers, eleven coal bunkers, and eleven coke bunkers. Attached to each range is a Babcock and Wilcox water-tube waste-heat boiler through which the waste gas is passed before entering the chimney. Range D, however, contains 32 7 ton retorts. There are eight producers in this range (four situated at each end), two coke bunkers, and two large coal bunkers, and there is an attached water-tube waste-heat boiler. The retorts of range D, which had been in operation for a period of five years without resetting, were not in good condition. The waste-heat boiler, however, appeared to be in good working order, and the dispositions of the producers and of the coal and coke bunkers were such that the examination of the producer gases, and the determinations of the weights of coal and coke used, presented fewer difficulties than in the case of any of the other ranges. In view of these and other considerations, and since the main object was to examine the performance of a waste-heat boiler, it was decided to select range D for the first part of the investigation.

Preliminary experiments were first made with the object of devising satisfactory methods of obtaining the essential data. Two tests, each extending over a period of five days, were then conducted, and the whole of the information considered necessary was procured. From the data obtained, heat equations were constructed for the purpose of ascertaining the volumes of waste gases passed through the boiler per hour. From these volumes and the known compositions of the gases, the equivalent weights of carbon were then determined. These weights should have been approximately the same as the weights of carbon gasified in the producers, provided that no leakages of gas through the retort walls or past the dampers closing the flue leading direct to the chimney had occurred.

The examination of the waste-heat boiler under such conditions would have been a comparatively simple matter. It was soon found, however, that the problem was much more complex, for the weight of carbon carried by the gases passed through the boilers per hour exceeded the weights gasified in the producers by approximately 300 lbs. in each of the tests on range D. The weights of carbon gasified in the producers per hour averaged 1940 lbs. A method involving the construction of carbon, water, and heat equations was therefore devised, for the purpose of ascertaining the approximate amounts of the various leakages which must have taken place. From these equations it was found that approximately 100 lbs. of the difference in carbon weights in test 1, and 200 lbs. of the difference in carbon weights in test 2, were due to leakages of waste gas past the by-pass dampers and back again into the boiler. The remaining weights of the carbon—viz., 200 lbs. in test 1, and 100 lbs. in test 2—therefore represent the excess of leakages of coal gas, &c., from within the retorts over any leakages of waste gas which may have occurred through the retort walls in the opposite direction. The equations also proved that in addition to leakage of air into the waste-gas flues, water had entered an underground flue.

The leakage of gas past the by-pass dampers back again into the boiler is best understood by reference to diagram I. From this diagram it may be seen that the waste gases from the range travel into an underground flue, from which they enter the boiler before passing to the chimney. The pull on the inlet boiler side of the by-pass damper near position 8 was greater than on the opposite or chimney side; and since dampers of this type situated in hot flues cannot in ordinary practice be made perfectly gas-tight, some of the gas which had already travelled through the boiler leaked back again to the inlet of the boiler.

The amounts of steam raised during the first two tests were respectively 95·7 p.ct. and 95·6 p.ct. dry. The method used for determining the quality of the steam is described in the body of the Report, and a typical example is given in the Appendix.

Since the performance of the waste-heat boiler attached to range D had been influenced, among other factors, partly by leakage of gas through the retort walls, and partly by the leakage of water into an underground flue, a further test was carried out on range E, the retorts of which had been reset early in 1923, and in which the waste-gas flues are all situated above ground level. The weight of carbon gasified in the producers in this third test was 2520 lbs. per hour, compared with 2810 lbs. in the gas passed through the boiler as deduced from a heat equation. The arrangement of the flues and boiler of this range is such that is was not possible to secure data which would enable the construction of the three simultaneous equations for carbon, water, and heat as in the two tests on range D. Comparisons of the compositions of the waste gases and the producer gases, however, led to the conclusion that the leakages of gas (if any) through the retort walls were small. It would thus appear that the 290 lbs. carbon difference in test 3 is to be accounted for mainly by leakages past the by-pass dampers.

The boiler attached to range E included an integral superheater, with the result that the temperature of the steam was raised to 306° C. at a gauge pressure of 132 lbs. per sq. in.—*i.e.*, the amount of superheat was 126° C. The amounts of water evaporated in the boilers during the three tests were equivalent to evaporations from and at 100° C. of 39·4, 42·5, and 53·4 lbs. per 100 lbs. of coal (dry basis) carbonized, or 2·97, 2·85, and 3·41 lbs. per pound of coke (dry basis) supplied to the gas producers.

Expressed as percentages of the heat values of the fuel supplied to the producers, the net quantities of heat recovered were 20·7 p.ct., 20 p.ct., and 24·2 p.ct. respectively in the three tests. In the absence of waste-heat boilers it would have been necessary to raise the same amounts of steam in boilers fired with solid fuel. On the basis of an efficiency of 70 p.ct., the solid fuel boilers would have consumed 8·6 tons of coke per day in test 1, 8 tons in test 2, and 12·1 tons in test 3; the qualities of the coke being the same as those actually supplied to the producers. These weights therefore represent the amounts of fuel saved per day by the waste-heat boilers, quite apart from a reduction in labour charges. It has been calculated that the amounts of heat recovered in the waste-heat boilers in this investigation would bring up the efficiencies of gas production in normal working with continuous vertical retorts by about 6 p.ct.—*e.g.*, from 60 p.ct. to 66 p.ct. The results, therefore, confirm the conclusion made as the result of calculations from the data given in the Fourth Report on the work carried out at Uddingston.

The leakages of waste gas past the by-pass dampers back again into the boilers cannot have had any marked influence on the amounts of steam raised, since these gases entered the boilers at temperatures not very much lower than those at the outlets of the boilers. From the compositions of the samples of waste gas taken at different points, however, it has been shown that large volumes of air must have leaked into the boiler settings and into the waste-gas collecting flues. It has also been concluded that, if leakages of air were eliminated, the gases passed through the boilers should contain approximately 18 p.ct. of carbon dioxide. The gases at the outlets of the boilers actually contained only 11·3 p.ct. of carbon dioxide in test 1, 11·2 p.ct. in test 2, and 10·3 p.ct. in test 3. The volumes of air which would be required to bring about the necessary dilutions of carbon dioxide from 18 p.ct. have been calculated; and in addition the amounts of heat carried by these volumes of air at the temperatures at which they left the boiler have been deduced. These amounts of heat, expressed as percentages of the heat values of the gases which entered the boiler, are 12·3 p.ct., 13·6 p.ct., and 14 p.ct. respectively in the three tests. If air leakages were eliminated, the whole of these quantities of heat would not necessarily be utilized in raising steam, but large proportions would be recovered, with resulting improvements in the efficiencies of the boilers. The prevention or reduction of air leakage is therefore worthy of consideration.

Finally, I must say that I cannot conclude the introduction of this Report without expressing how very much I personally, and my assistants, have appreciated the great kindness shown and the excellent facilities granted to us by the officials of the Birmingham Gas Department—Mr. A. W. Smith (General Manager), Mr. Foster (Chief Engineer), Mr. Rhead (Chief Chemist), Mr. Pearson (Engineer at the Windsor Street Works), and Mr. Bamber (Adderley Street Works). We have spent a very happy and interesting four years in Birmingham. I must also express my debt of personal obligation to Mr. H. Kerr, Dr. A. C. Monkhouse, and Mr. G. B. Howarth for their valued assistance as members of the Research Staff.

Discussion.

Mr. J. S. THORMAN (Stratford): It gives me very great pleasure to move the adoption of this report; and I may perhaps be allowed to take the opportunity of passing a few comments upon it.

I am glad of this opportunity of expressing my appreciation of this report giving so fully and in such detail the results and the methods by which they have been obtained. Such work is of inestimable value to the gas industry. The calculations of the carbon figures obtained from the actual fuel used in the generators compared with the total carbon content found in the waste gases are very interesting. Any extra carbon coming from the gas leaks is indicated, and thus a better control over carbonizing is obtained through the installation of waste-heat boilers. A further important point bearing on the subject of improved carbonization control is that the pull on the settings can be maintained absolutely constant, and is not dependent on weather conditions. In the early part of the report, one of the points which struck me was the excellent working of the producers. We get up to as far as 13 p.ct. of hydrogen, and the calorific value is 124 B.Th.U., which is, I think, in itself, a great accomplishment. In comparing the three boilers, it is notable that No. 3 is the most efficient by a considerable amount; and one notices that the heating area has been reduced from 4315 to 3176 sq. ft. Superheaters are fitted to this boiler, and it may be due to these that we get the higher efficiency; but in considering the outlet temperatures of the three tests there is a point which strikes me very forcibly. In the first test the outlet temperature is 308° C., in the second 324° C., and in the third 265° C.; and after all the expense of installing waste-heat boilers, it is a little disappointing that the outlet gases are at such comparatively high temperatures. There is no reason in our experience why these temperatures should not be brought down to the figure of 223° C. If such a result had been obtained, there would have been roughly an increase of about 28 p.ct. in the heat recovered in the first two cases, and 18 p.ct. in the case of the boiler in the third test. The steam evaporated per lb. of fuel was 3½ lbs.; and had these gases been brought down to the not unreasonable figure of 220° C., I think we should have had approximately 4 lbs. of steam per lb. of fuel. Dr. Parker has frequently referred to the by-passing of the gases and recirculation through the boiler. I notice from the figures that the chimney shaft is doing nearly 50 p ct. of the work and taking 50 p.ct. of the load, thus relieving the motor driving the fan; but it has introduced the objection of dilution, which, as has been pointed out, it is desirable to avoid as much as possible. It is an open question to my mind whether it is worth while delivering these gases back into the chimney shaft and thereby obtaining a considerable relief on the load on the motor, rather than delivering to the atmosphere. Gases of the temperature of 220° to 250° C. are of considerable value, and might be made use of in water heating, or for other purposes. There is one point that I rather want to ask Dr. Parker about. I notice that the draught at the base of the chimney shaft in the first two tests was given as 0·9 in. of water, but in the third case the temperature was very much lower; being reduced to 265° C. Can Dr. Parker tell me what effect this had on the chimney draught, because in the data given this particular figure is missing?

With regard to the remarks on normal working, one can well imagine there was a tendency to run the settings rather heavier than would be the case if the steam was in large demand. This gives that elasticity which is so very valuable at times; but I think that when the fuel figure is taken on any boiler test, this should determine whether the working should be normal or otherwise, and the lbs. of steam per lb. of fuel carbonized should be taken into consideration in considering waste-heat boiler evaporation in this respect. With reference to the type of boiler, I have not had any experience with water-tube boilers. Our experience is limited to firetube boilers with 1¾-in. diameter tubes; but there are several advantages in my opinion with firetube boilers which might be mentioned. The great advantage is that the firetubes can be cleaned while the boiler is at work. It only means that one or two of the battery of tubes have to be exposed to the atmosphere while the cleaning takes place. The cost of cleaning a firetube boiler works out at about 2s. for labour, and it can be done twice a week, at a low cost, and the boilers kept in very fine condition.

With reference to the water which was used in these tests, the Birmingham Works have been happy in the quality of their water, as apparently there is only about 5° of hardness; but, when you are getting a high evaporation from a limited surface, I should prefer to maintain zero hardness. At Stratford we have been running waste-heat boilers continuously day and night for seven months, and as the result of using water with zero hardness, the tubes on the water side are in perfect condition and as good as when they were first installed. There is a note at the end of the report on the steam raised per sq. ft. of heating surface, and it is suggested that it is important to note this figure. In comparing the same type of boiler, this is of importance; but in comparing water-tube with firetube boilers it does not appear to me to be a vital factor. We made a rather interesting experiment at my works, where we had, in one case, all the tubes at work, and we got a steam evaporation of 3·85 lbs. of steam per sq. ft. per hour. With 33 p.ct. of the tubes stopped, thus giving very much greater velocity, the evaporation increased to 5·07 lbs., so that the result of increasing the heating surface by 33 p.ct. was greatly to increase the steam evaporated per sq. ft., and thus the efficiency of the boilers. I notice in the report that the boilers have to be cleaned every four months, and that most of the tests were

taken within a month of cleaning, though there is one test which went two months longer in which the outlet temperature of the gases was considerably higher. I think it was 324° C. It is rather an important point if one is going to instal waste-heat boilers to deal with the total steam of the works, if the boilers have to shut down some considerable time for cleaning.

Perhaps it would be interesting to give you some results at Stratford after seven months' continuous night and day running with firetube boilers. Without any cleaning, observation, or attention the falling-off in efficiency was only 6 p.ct. We have no figures of capital cost of water-tube compared with firetube boilers, but I am of opinion that the advantage in favour of the firetube boiler in the matter of boiler setting should be of the order of 50 p.ct. There is one other point. It is rather notable that the greater part of the information which has been placed before the industry as regards waste-heat boilers has been confined to water-gas plant or verticals; but I do not see why this work should not be extended to horizontals, because in horizontal plants we have opportunities of raising practically as much steam as has been mentioned in the report.

In horizontal plants, with a combustion-chamber temperature of 1350° C., the gases on their last travel must be at least 1000° C. Many engineers have told me that there is no temperature colour in their waste-gas flues. Why is this? How have the waste gases been cooled from 1000° to (say) 400° C., at which no colour can be observed? I cannot follow what has reduced the temperature of these gases. So far as we know we only have the secondary air; and as there are two volumes of waste gases to one volume of secondary air, it is impossible for these gases to be reduced in temperature by the secondary air, no matter how efficient the regenerator is. The conductivity of the firebrick is indifferent, as compared with metal, for instance; and according to calculations from the available formulæ, the waste gases can only be cooled by secondary air from 250° to 300° C. according to the design and efficiency of the regenerator. The real difficulty that is causing this trouble is the dilution of the gases; and I have some figures of dilution which I think may be interesting. With 19 p ct. of CO_2 in the waste gas, there will be no dilution; with 16 6 p.ct. of CO_2, there will 25 p.ct. dilution; with 14·6 p.ct. of CO_2, there will be 50 p.ct. dilution; with 11·8 p.ct. of CO_2, there will be 100 p.ct. dilution; and 9·93 p.ct. of CO_2 represents 150 p.ct. dilution. Therefore, when one has these figures in front of one, it can be realized that, if the temperature of the waste gases is down, it is entirely due to dilution. I have made some calculations which show that without dilution the waste gases in a horizontal setting could not be reduced by much more than 250° C., so that we should have the waste gases coming away at about 750° C., the combustion-chamber temperature being 1350°, and the temperature of the gases at the inlet to the generator 950° to 1000° C. From the report, we have seen that gases of such a temperature will raise up to 3½ lbs. of steam per lb. of fuel; and if the gases in the test referred to in the report had been reduced to 220° C. at the outlet of the boiler, the figure would have been practically 4 lbs. of steam per lb. of fuel. I am prepared to state that in average working with horizontal retorts we could raise 4 lbs. of steam per lb. of fuel used in the generator, which, at 14 p.ct. fuel consumption would represent about 1200 lbs. of steam per ton of coal carbonized. In taking the requirements for steam on a gas-works, we get a figure of about 720 lbs. of steam required for all purposes, including an allowance of 10 p.ct. for distribution, per ton of coal carbonized; and if I include another 130 lbs. for sulphate of ammonia production, we get a total figure of 850 lbs.; and there are available, as I have shown, 1200 lbs. which can be supplied from waste heat. It is therefore obvious that all the power requirements on a gas-works can be more than supplied from the waste heat. A well-known consulting engineer told me that he has found, from his experience on various works, that the fuel used for general works purposes is roughly 10 p.ct. of the total weight of the coal carbonized, so that the figures are very large ones and well worth the consideration of engineers. I hope therefore that in the future it will be the exception rather than the rule for there to be an absence of waste-heat boilers.

Mr. J. FERGUSON BELL (Derby): I have pleasure in seconding the motion for the adoption of the report.

Mr. J. P. LEATHER: We do not want to spend very much time in discussing the report, because it is one which we want to read at our leisure, and see how it bears upon our own practice in our own works. At the same time, I thought I would like to rise and express my appreciation of the work of the Committee with regard to waste-heat boilers, because it has emphasized what too many of us have neglected in the past. It is some 40 years ago this year since we put in a waste-heat boiler in the works where I was working under my father, for steam to be produced from waste heat. They were horizontal settings worked with old direct-fired furnaces, and I know that at times that boiler produced all the steam that was required. Unfortunately, it was somewhat irregular, no doubt because we had not realized the difficulties and points which we should consider, and which this report emphasizes—viz., the avoidance of leakages of air into the flues, and speaking generally, the conservation of heat. There is an enormous amount of waste heat in a gas-works; and I go so far as to say that no really modern gas-works ought to have solid-fuel boilers at all, and they ought to be producing surplus steam to generate electricity for the supply of their district. There is more heat wasted on a gas-works than is necessary for producing the steam and for dealing with the power that is required on the works; and therefore it is possible to have surplus steam to sell to other people. In the report we see that there are approximately 3 lbs. of steam per lb. of fuel burnt in the producer. I believe that in many cases, if gas-works boilers were tested, it would be found that only 6 or 7 lbs. of steam were obtained for every 1 lb. of coke burnt in the boilers, and that a very large proportion of the heat of the coke burned in the furnaces was being lost. The boilers which have been tested by the investigators in this research are certainly working very badly. In other words, they have not conserved the heat, because they have allowed a considerable proportion of air leakage. We are most of us, if not all, wasting heat in our settings by radiation and convection; so that if we were a little more careful I am sure that we should have heat to spare and steam to sell to somebody else.

Mr. G. C. PEARSON (Birmingham): I did not come to this meeting with any intention of taking part in the discussion; but there are one or two points mentioned by Mr. Thorman to which I should like to refer. I should like to say that the waste-heat boiler installation at the Windsor Street Works is not what we should consider now as best modern practice. I think I am right in saying that the boiler put down in D section was the first waste-heat boiler installed with Woodall-Duckham settings of that size, and it had underground flues to the chimney, through which by-passing is taking place, which is undoubtedly a mistake. In our new works at Nechells we have put overground steel flues, which obviate the difficulties which Dr. Parker has experienced in carrying out these tests. With regard to the greater efficiency obtained in No. 3 test, I think this arises from the design of the boiler, though there is less area in that boiler. In D section, the first boiler we put down had tubes 14 rows by 14 deep, and we found by experience that the higher the rows of tubes and the narrower the boiler, the greater the efficiency. The E section was constructed in 1912, but the waste-heat boiler was put down 10 years later, and in this we had 16 rows by 7 tubes deep. With regard to the efficiency of water-tube and firetube boilers, we have no doubt that the firetube boiler is the more efficient; but from the working point of view, we are of the opinion that the water-tube boiler gives the least trouble. This has particular relation to the matter Mr. Thorman pointed out—the cleaning and the scaling of the boilers. The use of Birmingham water without erecting an expensive softening plant would cut out firetube boilers. We get very little trouble with flue dust; the difficulty being caused only by scale. By cleaning once every four months, and using once in 12 months a rotary boiler-scaler, we are able to keep the tubes clear. When the whole installation at Windsor Street is working, we have more than sufficient steam; so that to shut down a boiler is not a serious matter. We have enough steam to run the works, steam all the verticals, and run two water-gas plants. There is one point I should like to mention. I have already referred it to the Gas Investigation Committee, and perhaps it might not be out of place to mention it here, and that is that in the course of Dr. Parker's investigations he has found that leakages take place from a setting, and he has been able to put a value to the quantity of carbon leaking. Where you have a large works and a number of units working together, it is not possible to tell what each particular unit is doing; and we judge by the general working as to when repairs shall take place. But there must be an economic limit to which you can work, and this possibly may be told in the future by the quantity of carbon leaking. If chemists could tell us when the leakage has reached such a figure that it is not economical to work the setting, it would tell us when it was necessary to repair. I think this would be a fine investigation.

The PRESIDENT: Prof. Cobb pointed out this morning that contributions will be welcomed to the discussions on these reports in writing; and we hope that as many as possible will find it desirable to do this later, in place of the spoken word.

Mr. T. HARDIE (London): I should like to refer to the question of the thermal and economical efficiency of gas production. Dr. Parker takes the efficiency of the setting used in the Fourth Report and the efficiency which he obtains with this boiler, and then adds the two together and suggests that this is what we might consider the thermal and economical efficiency of gas production. No connection between the two investigations is possible, however, because the conditions under which the test in the Fourth Report were made were quite different from the conditions that exist here. The waste-heat temperatures, in the first place, were very much higher, with the result that an additional advantage will have been received from the higher temperature of the waste heat, in considering the total efficiency of gas production. This, together with the figures of efficiencies which could be obtained either from this boiler or other boilers working under more efficient conditions would increase very much that general efficiency which is put down somewhere in the neighbourhood of 66 p.ct.

Dr. PARKER, replying to the discussion, said: I am very pleased at the interest which has been taken in the report, and the interesting discussion which has followed. With regard to the points raised by Mr. Thorman, a number of them were particularly directed to showing what can be done with different types of waste-heat boilers, and how much heat there is to be recovered from horizontal settings. With many of those points I agree. A few of the problems raised by Mr. Thorman require a little more elucidation, and Mr. Pearson has dealt with them; but perhaps I might refer to them again. Mr. Thorman referred to the

temperatures of the gases leaving the boilers in the three tests as 308°, 324°, and 265° C. respectively. This is correct; but he thinks these temperatures disappointing. In this case we were dealing with water-tube boilers without economizers, and it is not right to put the temperatures in too definite an order (say) 308° and 324° C, and then say the difference between the two is due to the fact that the boiler had been more recently scaled in the first test than in the second, because other factors come into play. There is, for instance, the extent of the leakage of coal gas through the retorts, which is burned in the waste-gas flues, owing to leakage of air through the brickwork; there is also the amount of leakage of air, and the position of that leakage. It is conceivable that the waste gases coming from a boiler may enter at a definite composition, and may almost reach the outlet of the boiler without dilution, but there may be a crack in the brickwork, and a large amount of air leakage after the gases have really done the work on the boiler tubes; and this would result in a lower temperature at the outlet than in the middle of the boiler. A lot depends upon the position of the leakage, as well as the amount, in considering outlet temperature. Of course, the temperatures could be lowered by the installation of economizers, but so far as I can gather, there may be some difficulty in this respect. I understand that a number of works have experienced trouble with economizers. It may be due to the composition of the water producing corrosion, owing to the slow evolution of oxygen from the water and the oxidation of the metal. Also, in shutting a boiler down, the gases coming from the boiler are cooled, and the condensed moisture dissolves sulphur dioxide, and the acid reacts on the metal. Thus, whether or not it would prove advantageous to work these gases any more is still a point which requires a good deal of investigation. Mr. Thorman is evidently very fortunate at his works in getting water which possesses no hardness. It would certainly remove the difficulties of scale. Then as regards the 3½ lbs. of steam raised per lb. of fuel in the third test, as compared with 3·36 lbs. in the first and second tests, the gases entered the boiler in that test at a much higher temperature than in the first, partly owing to the fact of the flues being above-ground, and because there was no leakage of water into the flue, and no cooling of the gases by the evaporation of that water. Then it is not correct to assume that if you have a bigger surface area you necessarily have a bigger evaporation. The velocity of the gases through the boiler also comes into play. If you had a boiler too big for this work, the gases would not be travelling fast enough to be stirred round and brought into intimate contact with the tubes. They would travel by the shortest route, and the whole of the surface area would not be utilized to the full advantage. In the case of fire-tube boilers, I understood Mr. Thorman to say that by increasing the velocity you get a bigger evaporation and a greater efficiency. I think this is due to turbulence and contact, but, of course, there is another point to be taken into account—the higher the velocities of the gases from the boiler, the more the power required to run the fan for the induced draught; and you have to set-off against the steam-raising power the power required to drive the fan. The whole subject is really bristling with difficulties, and all sorts of points have to be taken into account. I do not agree that in boiler testing it is sufficient to take account of the fuel supplied to the setting and the steam raised, and I thought we made this clear in the report when we pointed out that the steam raised does not amount to what one would expect if the whole of the waste gases came from the fuel in the producer, owing to leakages of actual gas from within the retorts to the waste-gas flues, thereby increasing the amount of waste heat. It has already been pointed out by Mr. Pearson in the discussion that this method, further developed, may form a means of measuring the leakages and the waste of coal gas, &c., through retort walls, and thereby of judging the conditions of the setting. I do not think there are any points to answer in Mr. Leather's remarks except that he said that the boiler was working very badly from what can be managed theoretically. Perhaps that is so, and from the comparative point of view of what is being done at the present time I do not think it is the correct way of raising a fair amount of steam. Certainly it could be improved by reducing the air leakages; but at what expense? I leave to the engineers to decide whether it would require brick-lined metal flues or tongued and grooved bricks to overcome these leakages. The economic side of it requires to be considered. I think I have dealt with the main points raised in the discussion.

Mr. THORMAN: There is one point which possibly I did not make quite clear. Dr. Parker has referred to the water which we have at Stratford as being very good. As a matter of fact, this water is reduced to zero by a Permutit softener; and I should like to tell the representative from Birmingham that this plant is of low cost. The capital outlay is negligible compared with the value of the work done. Our water has really 20° of hardness, but there is no difficulty in reducing it to zero.

The report was adopted.

GAS INVESTIGATION COMMITTEE.

COMMUNICATION TO THE GAS RESEARCH SUB-COMMITTEE FROM THE LABORATORIES OF THE SOUTH METROPOLITAN GAS COMPANY MADE WITH THE PERMISSION OF DR. C. CARPENTER.

Introductory.—At a meeting of the Gas Investigation Committee held June 11, 1923, in a discussion on the programme of research work, a subject which received attention was the practicability of schemes proposed, and processes described, for the partial or complete elimination of carbon monoxide from town gas supply, and its replacement by methane. During that discussion, Mr. E. V. Evans, of the South Metropolitan Gas Company, informed the Committee, of which he is a member, that laboratory work upon the subject had been carried out by the Company, and expressed his conviction that Dr. Carpenter would be quite willing for an account of the work to be placed in the hands of Prof. Cobb, so that any unnecessary expenditure of time and duplication of experimental work might be avoided. The Committee were very grateful for the suggestion and the offer. Since that time, with the consent of Dr. Carpenter, this interesting communication upon a subject of great importance has been made, and the Gas Investigation Committee, on the advice of its Gas Research Sub-Committee, have recommended its publication.

THE SYNTHESIS OF METHANE AND THE REMOVAL OF CARBON MONOXIDE FROM WATER GAS AND COAL GAS.

The interesting problem of the economic production of a non-poisonous gas by elimination of carbon monoxide is one which has recently received considerable attention in gas industry circles, and an investigation was instituted in this laboratory with a view to devising, if possible, a cheap and efficient process to attain this end.

It is generally agreed that the removal of carbon monoxide can be best achieved by making use of the fact that in the presence of suitable catalysts this gas reacts with hydrogen and steam in accordance with the following equations:

$$CO + 3H_2 = CH_4 + H_2O$$
$$CO + H_2O = CO_2 + H_2$$

These reactions may be applied to both—

(1) The conversion of water gas to a methane rich gas.
(2) The replacement of carbon monoxide in ordinary straight coal gas by hydrogen or methane or both.

A fairly comprehensive study of these reactions has been made in this laboratory, and the results obtained have rendered possible a much clearer conception of the technical possibilities of these processes.

(1) *Conversion of Water Gas to a Methane Rich Gas.*

The first attempt to apply the catalytic hydrogenation of carbon monoxide in industrial processes was made by Sabatier. According to his earlier patents* water gas containing approximately equal volumes of carbon monoxide and hydrogen is freed from sulphur impurities by passing over copper turnings at 600° C., and is then brought into contact with a metallic nickel catalyst at 400-500° C. Owing to the high temperature at which the reaction is effected, the process is complicated by a secondary reaction

$$2CO = C + CO_2$$

which takes place with great rapidity, causing considerable deposition of carbon on the catalyst. The latter, in consequence, soon becomes inactive, and frequent regeneration, accomplished by steaming at 400°-500° C., is necessary. A slight improvement in the process is effected by the introduction of steam into the gas before hydrogenation, as this tends to reduce the quantity of carbon deposited. The process, however, failed to produce any good practical results.

In a later patent† Sabatier suggests the use of a gas containing a smaller percentage of carbon monoxide, such as a producer gas containing as much as 24 p.ct. CO_2 and only 12 p.ct. CO. After the removal of the carbon dioxide and elimination of sulphur compounds by metallic copper at

* E. P. 15,234, 1906, and 15,326, 1906.
† E. P. 14,971, 1908.

600° C., Sabatier effects the conversion of carbon monoxide to methane with a metallic nickel catalyst at 350° C. The method of working a producer so as to obtain a gas with such a low carbon monoxide content is by no means an economical one, and, in addition, costly processes are involved in the removal of carbon dioxide and in the periodic regeneration of the copper, which ultimately becomes converted to sulphide. This process of Sabatier has for these reasons never been established on an economic basis.

The work of Sabatier showed that in order to avoid the deposition of carbon this reaction must be carried out at a low temperature and in the presence of an excess of hydrogen. This was confirmed by subsequent investigators who found that the temperature of the reaction should not exceed 285°-290° C., and that although the theoretical proportions of hydrogen and carbon monoxide for the hydrogenation reaction are 3 vols. H_2 to 1 vol. of CO, as many as 4·5 to 5 vols. of H_2 to 1 vol. of CO are required if the reaction is to proceed at reasonable velocity and without danger from carbon deposition. The work which has been carried out in this laboratory has been conducted with a view to increasing the velocity of the reaction by means of a more active catalyst. The reaction was effected at a temperature of 285°-290° C. with a mixture of H_2 and CO in the ratio of 5 : 1 parts by volume, and the effect upon the velocity of the reaction of introducing various activators was examined. It was found that the rate of reaction could be considerably increased by the use of an activated catalyst, the optimum results being obtained with a nickel thoria catalyst which gave a maximum speed of 600 cc. per minute for 0·1 grm. of catalyst. The speed for the same quantity of nickel was 35 cc. per minute. The reaction velocity has hence been increased seventeenfold by the use of an activator.

In addition to confirming the observations of other workers concerning the temperature at which the reaction should be effected and the required proportions of H_2 and CO in the gas mixture, it was also found that in the presence of about 20 p.ct. CO_2, using a nickel thoria catalyst, the reaction could be effected at a rapid rate with almost theoretical proportions of the reacting gases. It was shown to be very essential, however, that the gases should be practically free from sulphur impurities, since it requires an exceedingly small amount of sulphur, viz., 1 part of sulphur per million parts of gas, to poison the catalyst and bring the reaction to a premature end. Two problems, therefore, remain to be solved before the reaction can be considered to be technically applicable:

(1) The removal of sulphur impurities.
(2) The adjustment of the proportions of H_2 and CO.

In a process introduced by the Cedford Gas Process Company,* the sulphur impurities and a part of the carbon monoxide in the water gas were removed by liquefaction, leaving a gas of the required composition for treatment by the nickel process. The liquefaction process, however, does not appear to have been developed.

A more convenient method for the removal of sulphur impurities consists in the passage of the gas accompanied by steam over a heated catalyst, for at the same time the H_2 : CO ratio is adjusted according to the reaction:

$$CO + H_2O = CO_2 + H_2.$$

This reaction forms the basis of the ordinary water gas process for the manufacture of hydrogen, which consists in passing water gas mixed with steam (previously freed as completely as possible from sulphur and other impurities) over a catalyst at temperatures of 450° C. and upwards. Any sulphur compounds remaining are converted into hydrogen sulphide, and the carbon monoxide can be fairly completely converted into carbon dioxide and hydrogen according to the above equation. The removal of the carbon dioxide and traces of hydrogen sulphide results in a hydrogen of about 93 p.ct. purity, containing nitrogen, about 3 p.ct. of unconverted carbon monoxide, and practically no sulphur impurities.

By reducing the ratio of steam to gas it should be possible to obtain any desired proportion of hydrogen and carbon monoxide in the final product. A careful study of this reaction in the laboratory has shown that it proceeds smoothly and rapidly at temperatures which are industrially applicable when nickel or iron is used as the catalyst in the presence of suitable activators. A particularly good activated catalyst consists of a mixture of iron and chromium oxide deposited on porous material. The laboratory experiments were carried out with mixtures of H_2 and CO in equal proportions by volume and not with water gas itself. The hydrogen, however, was found to contain traces of sulphur impurities, sulphides being easily detected in the catalyst after use. The quantity of sulphur impurities in the hydrogen could, however, not be estimated by ordinary methods. The results, therefore, should be comparable to some extent with those which would have been obtained had water gas freed from sulphur compounds by means of the Carpenter-Evans process been used. It was found that in order to effect a sufficiently complete conversion of the sulphur compounds into hydrogen sulphide, and to preserve the activity of the catalyst, it was necessary to work at temperatures in the neighbourhood of 550° C. Using an iron-chromium oxide catalyst deposited on five times its weight of pumice, it was possible to pass gas (H_2 : CO = 1 : 1) mixed with 2·5 volumes of steam at the rate of 200 cc. (gas) per minute over 0·2 grm. of catalyst and obtain a product of the composition:

18·2 p.ct. CO_2
19·4 p.ct. CO
62·4 p.ct. H_2 (including a small percentage of N_2)

For the purpose of the synthesis of methane, this mixture after removal of traces of hydrogen sulphide was passed over a nickel-thoria catalyst (0·2 grm. of catalyst on 1 grm. pumice) at the same speed and converted into a gas of the composition:

41·6 p.ct. CO_2
45·3 p.ct. CH_4
7·0 p.ct. H_2
remainder N_2

A mixture of approximately the same composition as water gas was thus converted by a two-stage process into a gas consisting mainly of carbon dioxide and methane in almost equal proportions with only a little hydrogen and nitrogen. It should be pointed out that no tests have been carried out over a long period of time in order to determine the life of the catalysts used, but little falling off in activity was noted over a period of several hours.

The above method of production of a methane rich gas free of carbon monoxide may be compared with a process recently suggested by Armstrong and Hilditch,* who state that the reaction

$$2CO + 2H_2 = CO_2 + CH_4$$

may be effected over nickel at temperatures of 240°-270° C. It will be seen that the final result of the two processes above described is practically the same, and Armstrong and Hilditch offer the explanation that the two reactions

$$CO + 3H_2 = CH_4 + H_2O$$
$$\text{and } CO + H_2O = CO_2 + H_2$$

proceed simultaneously over the nickel catalyst. This is doubtless quite true, but the process appears to be open to two serious objections—

(1) The reaction in accordance with the final equation
$$2CO + 2H_2 = CO_2 + CH_4$$
is very slow at temperatures of 240°-270° C.

(2) A sulphur-free gas is specified, but no explanation is offered as to how the last traces of sulphur compounds are to be removed before passing the gas over the catalyst.

The two-stage process outlined in this report would therefore appear to be the more practical. The main disadvantage of this process, however, lies in the fact that the synthetic gas thus obtained contains a high concentration of carbon dioxide which it would be necessary to remove from the gaseous mixture before distribution. It is doubtless the expense of this operation which is the deciding factor in the establishment of this process on an industrial scale.

Some idea of the cost involved in producing synthetic gas may be revealed by a consideration of the cost of producing hydrogen by the water-gas process. The same operations have to be effected in the case both of the production of water-gas hydrogen and of hydrogen for synthetic gas, but in the latter case there is the additional cost of subsequent hydrogenation. A minimum estimate, therefore, should be obtained by assuming the cost per unit of carbon monoxide converted to be the same in the two processes.

* Erdman. J. Gasbeleucht. 54 (1911), 737.

* Proc. Royal Society, 1923 (A) 103. 25-34.

Approximate Estimate of Cost of Production of Synthetic Gas.

Pre-war cost of water-gas hydrogen = 1s. 9d. per 1000 c.ft. (water gas at 4d. per 1000 c.ft.)
Estimated cost of water-gas hydrogen to-day . . . . . = 3s. 6d. per 1000 c.ft. (water gas at 8d. per 1000 c.ft.)

Assuming that the composition of water gas is 54 p.ct. H_2, 42 p.ct. CO, 4 p.ct. N_2—*i.e.*, 1000 c.ft. would contain

540 c.ft. H_2
420 c.ft. CO
40 c.ft. N_2

and that the composition of the water-gas hydrogen produced is 93 p.ct. H_2, 3 p.ct. CO, 4 p.ct. N_2—*i.e.*, 1000 c.ft. would contain

930 c.ft. H_2
30 c.ft. CO
40 c.ft. N_2

then the production of 1000 c.ft. of water-gas hydrogen requires the conversion of (420 − 30) = 390 c.ft. CO and the removal of an equal volume of CO_2.

Therefore, estimated cost of process per 100 c.ft. CO converted and CO_2 removed is

$$(3s.\ 6d. - 8d.) \times \frac{100}{390} = 8{\cdot}73d.$$

Now, according to the equation

$$CO + H_2O = CO_2 + H_2$$

1 volume of CO is replaced by 1 volume of CO_2 and 1 volume of H_2. Therefore, in the production of synthetic gas from 1000 c.ft. of water gas containing

540 c.ft. H_2
420 c.ft. CO
40 c.ft. N_2

200 c.ft. CO will have to be converted to give a gas for hydrogenation containing:

220 c.ft. CO
200 c.ft. CO_2
740 c.ft. H_2
40 c.ft. N_2

(A gas of this composition has been shown experimentally to be suitable for hydrogenation, *vide* page 5.) And according to the equation,

$$CO + 3H_2 = CH_4 + H_2O$$

3 volumes of H_2 are required for the hydrogenation of 1 volume of CO giving 1 volume of CH_4.

Therefore, after hydrogenation and removal of 200 c.ft. CO_2, synthetic gas will consist of

220 c.ft. CH_4
80 c.ft. H_2
40 c.ft. N_2

340 c.ft. of calculated calorific value 690 B.Th.U. per c.ft. = 2·34 therms.

Estimated cost of conversion of 200 c.ft. of CO and removal of CO_2 is 17·46d. = 7·5d. per therm of synthetic gas.
Estimated cost of 1000 c.ft. of water gas is . . . . . 8·00d. = 3·4d. " " " "
Total 10·9d. " " " "

Thus, excluding cost of hydrogenation process, estimated net cost of production of synthetic gas, free from carbon monoxide, and of calorific value 690 B.Th.U. per c.ft. is

10·9d. per therm.

Although this figure must be taken as a very approximate estimate, it is quite clear that the production of such a CO-free synthetic gas from water gas is economically out of the question unless some other much less expensive method can be found.

(2) *The Replacement of Carbon Monoxide in Ordinary Straight Coal Gas.*

This problem appears to be a somewhat simpler one than that of the production of CO-free gas from water gas, since the hydrogen and carbon monoxide are present in this case in suitable proportions for hydrogenation to methane. Unfortunately, however, the sulphur impurities must first be eliminated. The only way of effecting their removal to the necessary degree of completeness appears to be by means of steam and a suitable catalyst at about 550° C.* as in the case of the water-gas hydrogen process. With this process two possibilities are presented:

(*a*) The almost entire replacement of carbon monoxide by carbon dioxide and hydrogen together with the elimination of sulphur impurities.

(*b*) The partial replacement of carbon monoxide, the elimination of the sulphur impurities, and the subsequent hydrogenation of the remaining carbon monoxide.

(*a*) The equilibrium constant for the reaction

$$H_2O + CO \rightleftharpoons H_2 + CO_2$$

at 550° C. is about 0·22.

$$i.e.,\ \frac{p\mathrm{H_2O} \times p\ \mathrm{CO}}{p\mathrm{H_2} \times p\mathrm{CO_2}} = K = 0{\cdot}22$$

$$\text{and } \therefore \frac{p\mathrm{CO}}{p\mathrm{CO_2}} = 0{\cdot}22 \times \frac{p\mathrm{H_2}}{p\mathrm{H_2O}}$$

The following figures calculated for a gas containing 7 p.ct. CO, 2 p.ct. CO_2, and 50 p.ct. H_2 show the percentages of carbon monoxide remaining in the gas at the equilibrium point when varying quantities of steam are used.

Temperature 550° C.

Steam/Gas (By Volume).	CO/CO_2 at Equilibrium pt.	P.Ct. CO in Gas at Equilibrium pt.
0·2	0·76	3·3
0·4	0·33	2·0
0·5	0·26	1·6
1·0	0·12	0·8
2·0	0·05	0·4

Thus any attempt to effect the complete conversion of carbon monoxide by steam would not be economical owing to the large volume of steam required, and resort must be had finally to hydrogenation.

(*b*) A few laboratory experiments carried out with coal gas showed that the process for the removal of sulphur compounds and partial conversion of the carbon monoxide into carbon dioxide and hydrogen was complicated by the presence of unsaturated compounds in the gas. These compounds are fairly easily decomposed at the high temperature of the reaction with the production of carbon dioxide. Thus, in one of these experiments coal gas containing among other constituents

1·4 p.ct., CO_2
3·0 " unsaturated compounds
7·6 " CO

was mixed with 0·4 volume of steam and passed at the rate of 200 cc. gas per minute over an iron-chromium oxide catalyst (0·2 grm. on 1 grm. pumice) at 500° C. A gas was obtained containing

4·8 p.ct., CO_2
2·2 " unsaturated compounds
4·8 " CO

Increase of CO_2 = 3·4 p.ct.
Decrease of CO and unsaturated compounds = 3·6 "

Poisoning of the catalyst was comparatively rapid at this temperature, the amount of carbon monoxide converted falling by about 40 p.ct. in 2 hours. This is probably due to absorption of sulphur by the catalyst, owing to too low a reaction temperature (in the presence of sulphur compounds a temperature of about 550° C. was found to be necessary in the case of the water-gas hydrogen process), and it would seem that a higher temperature must be maintained if the activity of the catalyst is to be preserved. In view, however, of the extensive decomposition of unsaturated compounds even at 500° C. in the presence of excess of steam, a process involving a still higher temperature and, in consequence, an even greater loss of these valuable constituents of the gas, would not be acceptable to the gas industry. In addition, the conversion of carbon monoxide to carbon dioxide would involve in any case a process for the removal of carbon dioxide which would add still further to the cost. What is needed is some low temperature process for the *complete* removal of sulphur impurities from coal gas—the coal gas containing no more than 1 part sulphur compounds per million parts of gas. With such a process, the removal of the carbon monoxide and its replacement by methane could

* The process employed by the S.M.G. Co. which is operated at 400° C. does not remove sulphur compounds to the degree necessary to obviate poisoning of the hydrogenation catalyst.

be effected very simply at a moderate temperature by direct hydrogenation. Even in this process, however, an appreciable loss in heat units (about 4 p.ct.) due to the exothermic nature of the hydrogenation reaction would be involved.

The results of the investigation may be summarized as follows:—

(1) It has been shown that the velocity of the CO, H_2 reaction for the synthesis of methane may be increased seventeenfold by the use of an activated catalyst—viz., nickel thoria.

(2) In the synthesis of methane from water gas a technical process has been outlined, but, owing to the necessity for removing sulphur compounds and for adjusting the proportion of carbon monoxide and hydrogen for the hydrogenation reaction, this process would prove too costly to be applied in the gas industry.

(3) In the case of coal gas, the preliminary removal of sulphur compounds to the required degree would involve partial elimination of valuable unsaturated hydrocarbons, and also conversion of part of the carbon monoxide to a useless gas, viz., carbon dioxide. In addition, a further heat loss is incurred owing to the exothermicity of the reaction, and the total loss resulting from these three factors would cause a considerable increase in cost per therm of gas produced.

Prof. COBB, introducing the communication, said: This communication comes from the South Metropolitan Gas Company, and Mr. Evans is here to give some account of it; but I might explain briefly how it comes to be given. Though the gas industry offers no endorsement whatever of the engineered carbon monoxide scare of last year, it is naturally and rightly interested in any practical proposals that may be made for the complete or partial elimination of carbon monoxide from coal gas or water gas. The ultimate test of any such process would, of course, have to be made on a working plant, but there are some preliminary questions which may be answered by laboratory experiment. When this subject was under discussion at a meeting of the Gas Investigation Committee, Mr. Evans told us that laboratory work on this subject had been undertaken by the South Metropolitan Gas Company, and that he was certain that, in order to avoid unnecessary expenditure of time and duplication of experimental work, Dr. Carpenter would be willing to place the results in the hands of the Research Sub-Committee. We were very pleased to accept the offer. As might have been expected, the communication proved to be a most interesting and important one, and the Gas Investigation Committee, on the advice of the Research Sub-Committee, have now recommended its publication for your information and discussion. I should like to express my own personal appreciation of its interest and value.

The PRESIDENT: I will now ask Mr. E. V. Evans, of the South Metropolitan Gas Company, to give a summary of the communication.

Mr. E. V. EVANS: My Company are privileged by having been allowed to place for the consideration of the Gas Investigation Committee their work on the synthesis of methane and the possibility of removing carbon monoxide from water gas and coal gas by its conversion to methane by catalysis. The name of Sabatier has become renowned by his discoveries, in which he has shown it possible to alter the nature and value of many organic substances—gases, liquids, and solids—by causing them to combine with hydrogen. He has done this in the presence of a catalyst; and the catalyst most favoured by him was metallic nickel. In 1905 he patented a process based upon this principle of hydrogenation, in which carbon monoxide could be hydrogenated, with the formation of methane. This means that in water gas containing both carbon monoxide and hydrogen, methane may be produced; and the possibility of fortifying water gas by producing from its own constituents the very valuable hydrocarbon methane has for many years been a matter of fascination to chemists in the gas industry. It is generally acknowledged that the addition of methane to water gas would add just that stabilizer that the water-gas flame requires. So important, therefore, is this question of technically and economically manufacturing the methane water-gas mixture, which may rightly be termed synthetic coal gas, that its success would have constituted yet another step in our ideal of completely replacing solid by gaseous fuel. My Company have studied in considerable detail the reactions which take place in the manufacture of this methane-rich gas and water gas, and have also given attention to the problem of eliminating CO from ordinary coal gas and its replacement by methane and by carbon dioxide. The report is a little difficult to deal with in a short period, but I will attempt to abstract it in a few words. The process of Sabatier may be represented by the equation $CO+3H_2 = CH_4+H_2O$, in which you will see that the theoretical volumes of hydrogen and carbon monoxide required are three of hydrogen to one of carbon monoxide. As a matter of fact, the reaction proceeds best with five volumes of hydrogen to one of carbon monoxide. In water gas, as you know, the proportion is approximately 1 to 1; and this was Sabatier's great difficulty. He devised several methods to overcome it. One of these methods was to operate a water-gas generator in such a way as to produce a gas containing the required proportion of hydrogen and carbon monoxide, but this entailed also the production of a high percentage of carbon dioxide, and represented a very uneconomical operation. As an extension of the work of Sabatier, we have discovered that by selecting a more suitable catalyst the reaction may be caused to proceed at seventeen times the velocity of that of the original Sabatier process. This very largely reduces the size of the catalyzing plant, and naturally gave great encouragement to proceed with the technical application of the Sabatier process. This encouragement was accentuated by the fact that conditions were found which caused the reaction to proceed with hydrogen and carbon monoxide in the proportion of 3 to 1, instead of 5 to 1. The problem, however, resolves itself not only into economically adjusting the proportion of hydrogen and carbon monoxide, but also in removing completely all traces of sulphur compounds which, even in a concentration of one part of sulphur to a million parts of coal gas, poison the catalyst and bring it to a premature end. A combined method of increasing the concentration of hydrogen and simultaneously removing the sulphur compounds lies in the passage of water gas in the presence of steam over an iron-chromium oxide catalyst at 550° C. This process, which has been patented by the Badische Anilin und Soda Fabrik, was found to be satisfactory, and thus a technical means of manufacturing synthetic coal gas is by no means an impossibility. Though the process may be technically possible, it is not economical. The three main reasons are, first, that the heat losses involved in adjusting the proportion of hydrogen to carbon monoxide to that required are too great. Then there is the cost of removing the carbon dioxide which is inevitably produced during the reaction, and, finally, one has to remember the cost of completely removing the sulphur compounds from this particular type of gas. The final result leads one to the decision that the cost per therm of the final gas would be appreciably greater than that of coal gas made by the ordinary destructive distillation of coal, and so cause the process to be economically unsound. Finally, the question of the possible removal of carbon monoxide from ordinary coal gas by the application of this reaction has been studied. In this case the removal of the sulphur compounds to a figure below one part per million parts of gas—which is also necessary and is attainable by the iron-chromium oxide catalyst at 550° C. in the Badische process—causes serious decomposition of the coal gas itself; and I should like to add here that the process which my Company have adopted for the removal of sulphur compounds at 400° C. does not reduce the sulphur compounds down to the required limit. It has been found that the temperature of the Badische process—550° C.—is too high for the safety of coal gas. One gets an appreciable destruction of the unsaturated hydrocarbons; and this, coupled with the fact that by virtue of the introduction of steam a proportion of the carbon monoxide is converted to carbon dioxide, has led us again to the conclusion that this process is not an economically sound one. This work has been presented by Dr. Carpenter to the Gas Investigation Committee solely with the object, as Prof. Cobb has explained, of preventing overlapping of effort and not in any way as a contribution which is likely to modify our manufacturing methods. Indeed, it is, I fear, rather a disheartening communication; but it may serve the purpose of eventually leading to some further development. After all, chemists are not unused to disappointments in the laboratory.

The PRESIDENT: We have all heard with great pleasure Mr. Evans' brilliant exposition of the communication which has been received from the South Metropolitan Gas Company, and I am sure it is your wish that it should be received with an expression of thanks. Though the results are of a zero character, nevertheless it is a communication the Institution are glad to receive and to have in their proceedings. We are grateful to the South Metropolitan Company and Dr. Carpenter for permission to include this communication in our proceedings.

THIRTEENTH (SPECIAL) REPORT OF THE GAS INVESTIGATION COMMITTEE.

SUB-COMMITTEE *RE* STANDARD METHOD OF TESTING GAS COOKERS.

Adopted by the Committee, June 4, 1924.

This Sub-Committee was appointed at a meeting of the Gas Investigation Committee held on March 12, 1923, at 28, Grosvenor Gardens, S.W. A series of historical notes dated March 19, 1923, was prepared by Mr. A. E. Broadberry (the Chairman) from information supplied by Mr. W. T. Dunn, and circulated to the members of the Sub-Committee, which was appointed as follows:

Messrs. A. E. Broadberry (Chairman), the President of the Institution, C. F. Botley, E. V. Evans, T. Goulden, P. S. Hoyte, W. E. Price, T. F. E. Rhead, and W. J. Smith.

The Sub-Committee co-opted the following:

Mr. J. G. Clark (The Gas Light and Coke Co.), Mr. Arthur Forshaw, Dr. H. Hartley (Radiation, Ltd.), and Mr. James Wilson (Messrs. Wilsons & Mathiesons).

This Sub-Committee met on March 22, 1923, and after considering various matters connected with Oven Testing elected a small Committee consisting of Mr. A. E. Broadberry (Chairman), Mr. J. G. Clark, Dr. H. Hartley, Mr. T. F. E. Rhead, and Mr. Arthur Forshaw (Convener and Secretary), to consider, and if possible put forward, a standard test or tests. (Mr. Rhead subsequently resigned membership of the Sub-Committee and of the Small Committee before any meetings were held.)

The Small Committee, after holding various meetings, and carrying out experimental work, by courtesy of the Gas Light and Coke Co., at the Company's Stove and Meter Department, Fulham, for which Mr. Forshaw was retained, reported to a Sub-Committee at a meeting held on Thursday, November 1, 1923.

At this meeting the work done, results obtained, and recommendations put forward by the Small Committee, in the form of a Report read by Mr. Forshaw after an introductory and explanatory discourse by Mr. Broadberry, were examined and discussed, and the Report adopted.

The Sub-Committee further instructed the Small Committee to prepare its Report in such a form that it could be presented as the Interim Report of the Sub-Committee to the Gas Investigation Committee at its meeting on November 12, 1923.

At this meeting the Gas Investigation Committee adopted the Interim Report of the Sub-Committee, and authorized the continuation of the work with a view to clearing up various points unsettled up to that date, and to the production of a Final Report which should include practical cooking tests in addition to the physical and other tests specified in the Interim Report.

At a meeting of the Sub-Committee on April 28, 1924, the Small Committee presented its Final Report, which was unanimously adopted for presentation to the Gas Investigation Committee at its meeting on June 4, 1924. This report now follows:

FINAL REPORT OF THE SUB-COMMITTEE *re* OVEN TESTING.

As the result of our work, we have come to the conclusion that tests to ascertain the following information should be carried out on cooker-ovens:—

1. **The Normal Maximum Consumption.**
2. **The Factor of Safety.**
3. **The Temperature-Maintenance Consumption.**
4. **The Suitability for Cooking.**

None of these tests can be omitted. This applies particularly to that for ascertaining the suitability for cooking, since, as is mentioned elsewhere, an oven may satisfactorily pass the first three which are physical tests and yet fail to give good cooking results.

Taking each of these in order; after definition or explanatory note, a description of the form of test recommended by the Sub-Committee will be detailed. Following the tests is an Appendix containing details of apparatus required, test-room conditions, procedure, illustration of results obtained, and other useful information.

1.—THE NORMAL MAXIMUM CONSUMPTION.

By Normal Maximum Consumption is meant that maximum consumption which may be required for the initial stages of cooking operations.

Experience has shown that this consumption is not higher than such as will heat the oven up from cold to 400° F. in x [1] minutes.

For determining the Normal Maximum Consumption the following heating-up test is put forward.

Heating-up Test (H) for the determination of the Normal Maximum Consumption.

The ovens as received from the maker unluted [2] as to joints and doors (*i.e.*, without any attempt to improve it beyond what is normally provided by the maker) [3] shall be suitably attached to an experimental meter [4] and a pressure gauge. [5] A suitable adjustable governor must be provided before the inlet to the meter, adjusted to supply gas to the oven at 20/10ths pressure [6] or at the minimum pressure of the district, whichever is the higher. A thermometer is inserted through a hole in the door (which is closed), so that the bulb is centrally disposed with regard to the four walls. The vertical position is that of C, the central row of holes specified in the maintenance test (*q.v.*); the exact position being that of C^b_2.

These preliminaries having been attended to, the meter and clock [7] being at zero, the gas cock is turned full on, the clock started, and a light applied to the burners simultaneously.

As the hand of the clock passes the first minute, the meter is read to the nearest mark and the thermometer to the nearest degree. This is repeated at each successive minute up to 15, the readings being recorded.

After the 15th minute the meter is watched and the clock stopped as the meter hand makes the next full revolution. From this last reading the rate in c.ft./hr. is calculated.

To pass the test a packed oven must attain a temperature between 390 and 410° F. (400° F. being aimed at) in not more than 12 minutes; an unpacked oven in not more than 10 minutes.

It may be found that the specified temperature is attained in very much less than the specified time. The hourly consumption is then excessive; if so, it will be detected in the Factor of Safety Test. [8] (*q.v.*)

If the temperature is not reached in 12 minutes (or the shorter time where appropriate) the hourly consumption is too low and the injector-nipples must be carefully opened. [9]

The test is then repeated from cold. [10]

When the gas-rate and pressure necessary to heat the oven up within the specified time, have been determined (the result being expressed in B.Th.U. gross per hour and in B.Th.U. per sq. ft. of internal surface per hour) [11] the next test is proceeded with.

2.—THE FACTOR OF SAFETY.

Under conditions of use, as the result of variations in

(1) x will vary according to whether the oven is "packed" or "unpacked." In a packed oven x = 12 minutes; in an unpacked oven 10 minutes.

(2) See note (16) following the next test.

(3) and see Appendix paragraph 3b.

(4) Appendix paragraph 2a.

(5) Appendix paragraph 2b.

(6) The legal minimum pressure of supply.

(7) Appendix paragraph 2f.

(8) The Committee's experience is that as they leave the maker's hands ovens are usually provided with nipples and burners that burn more gas than is necessary to pass the test.

(9) As a rough guide it may be stated that in a packed oven of 14-in. door opening, an increase of 2-3 c.ft. per hour may reduce the time to heat up from cold by approx. 5 to 7 minutes, from (say) 20 minutes.

(10) Not more than two such tests may be made in a working day owing to the impossibility of cooling the oven down completely to normal air temperature. This applies with particular force to packed ovens which heat up much more quickly and easily than might be anticipated when they are apparently but 2° or 3° above the air temperature.

(11) Calculated as described under the maintenance test (*q.v.*).

pressure and density of the gas supplied, the oven may be called upon to consume more gas than the normal maximum consumption, and whilst the oven cock allows of control, it is necessary to ensure that the appliance shall be safe without the necessity of such external control.

The Sub-Committee feel that if an oven can consume safely such an excess of gas over the normal as will result from a pressure increase of 2½ times the minimum district pressure (at which the normal maximum consumption is ascertained) the appliance will be satisfactory.

For determining this the following test is put forward:

Smothering Test (S) to ascertain that the oven has a Reasonable Factor of Safety.

The oven is luted up [12] at all external joints, including those round the door, with cement. [13]

The pressure is set to 2½ times that used in the previous test. This will provide an increased consumption of approximately 60 p.ct.

The oven is lit up and observation made of the flames by means of a mirror which must not be bulky enough nor used in such a manner as to interfere with the normal flow of air to the oven.

Where the oven construction does not allow of the use of a mirror in this way, an observation hole or holes must be provided, covered with transparent material.

Floating or smothering [14] of the flames indicates failure to pass the test. If this condition cannot be rectified by adjustment of the air controls, then structural alteration of the oven is required. [15]

The approximate magnitude of the failure may be gauged by repeating the test, from cold, at a slightly lower pressure, say, 2¼ the district minimum, followed by twice the minimum, and so on until the flames no longer float or smother. It must, however, be repeated, to avoid misunderstanding, that the oven must pass the test at 2½ times the minimum district pressure—*i.e.*, the original pressure in the previous test (H).

In the above H and S tests (and in the M test which follows) no "furniture" other than the gates (where fitted) and one grid shelf, to keep them apart, are to be left in the oven, that being the normal state during the initial heating up. [16]

3.—THE TEMPERATURE MAINTENANCE TEST (M).

If the oven satisfactorily passes the two previous tests (H and S), its comparative value, as an apparatus for arresting the heat of combustion of the gas and maintaining a cooking temperature, is to be assessed.

For this purpose tests at two temperatures are necessary.

The oven is lit up unluted, and the gas supply manipulated either automatically by thermostat or manually until a mean temperature of not less than 370° F. above that of the test room is attained and has been maintained for two hours. [17]

In either case, when constant temperature conditions are apparently established, two consecutive readings of the meter, over not less than ten minutes each, must agree with one another. [18] When this is the case, temperature readings in the oven may be commenced.

For this purpose eleven holes are drilled in the oven door [19] as follows:

(A sketch, fig. 11, is attached, and if consulted whilst the following verbal description is being read, will help towards the visualization of the exact positions of the thermometer bulbs in the space to be explored.)

The eleven holes are divided into five groups and allow of 29 temperature readings as follows:

Three main groups lettered B, C, and D, vertically one above the next, B being uppermost. The members of each main group are disposed horizontally along the centre line of one-third of the space explored.

Each main group consists of three holes, letters from left to right, *a*, *b*, and *c*, being in one horizontal plane.

Each hole allows of three positions at which readings are taken, numbered 1,2, and 3, from back to front.

The above make, in all, 27 temperature readings.

There are, in addition, *two subsidiary groups consisting of one hole each* and lettered A and E. *Each hole* of these *allows of one position* at which a reading is taken. A is above B and E is below D, and the readings are taken purely as a check on the constancy of the temperature in the oven.

Any particular position inside the oven is precisely denoted by three indices, thus B^a_1 is the extreme top, left hand, back position in the three main groups of readings. Similarly C^b_2 is in all respects the centre reading of the space under exploration.

As the readings at A and E are also taken at positions centrally disposed with regard to the four vertical sides of the oven, they have been usually referred to as A^b_2 and E^b_2 to avoid any ground for confusion.

The exact space which forms the basis of comparison between two different ovens is that contained between the two sides, the back and the door, and the internal dome and the level of the burner teats, while of the above space, B, C, and D are 1-6th, ½, and 5-6ths of its height, from the top; a, b, and c 1-6th, ½, and 5-6ths of its width, from the left and 1, 2, and 3 1-6th, ½, and 5-6ths of its depth from the back, respectively.

A is ½ in. below the internal dome, and E is a convenient distance below the level of D.

In setting the oven temperature, reference is made to A^b_2, as, with all ovens so far tested, this position gives a temperature very close to the mean of the 27 to be subsequently taken.

To make the 29 temperature readings, *eleven* thermometers are required, viz.:

Three with long stems showing a considerable blank space between the bulb and the zero mark. These are used exclusively for the nine back readings at position "1."

Five with shorter stems and a shorter blank space, for use in the nine positions at "2" and in the two positions at A and E.

Three ordinary thermometers for use in the nine front positions at "3."

The thermometer at A, to the reading of which the oven is adjusted, should be inserted in the oven from the start.

Not less than half-an-hour before temperature readings are commenced, the remaining ten thermometers are inserted, and their positions checked by reference to the graduation which appears level with the front edge of the supporting cork. [20]

A convenient initial setting of the thermometers is:

All long ones at B^a_1, B^b_1, and B^c_1 respectively;

All medium ones at C^a_2, C^b_2, and C^c_2; and at A^b_2, and E^b respectively.

All short ones at D^a_3, D^b_3, and D^c_3 respectively.

After all these have been read and recorded they are transferred one by one (each vertical row being completed before the next is attempted); those at B1 to C1, those at C2 to D2, and those at D3 to B3; those at A^b_2 and E^b_2 remaining undisturbed.

---

(12) See note (16) following this test.

(13) *e.g.*, purimachous cement.

(14) Smothering takes place when two or more flames permanently leave either or both burners, and see Appendix 5 for notes on floating and smothering.

(15) *e.g.*, in respect of burner position or size and situation of the flue, &c.

(16) The oven is not luted during the H test, as under the specified conditions it will give the worst result, but in use, as cracks and so on tend to become filled up with grease and the like, it will tend to improve.

It is luted during the S test because luting represents the worst conditions from the point of view of safety, a condition towards which the oven tends during use. By luting during the S test the mistake of passing as perfect an oven that might become dangerous in time from the cause mentioned is avoided.

It is unluted during the M test for similar reasons to those given under H test immediately above.

But in a purely physical comparison of the insulating material of two similar ovens they should be luted, or differences due to different insulating properties may be masked by adventitious escapes of products at places other than the flue outlets.

(17) To ensure this condition by manual manipulation of the cock requires constant and unremitting attention. At the slight pressure in the oven-supply-pipe (approximately 5/10ths) which is usually all that is required to pass sufficient gas for the purpose, an increase or decrease of very small magnitude, such as might easily occur through improper functioning of the governor, or a slight alteration in the calorific value of the gas, is sufficient entirely to upset the temperature conditions. Under these circumstances, and whilst remarking that success may be ensured if manual manipulation is sufficiently painstaking, it is recommended that an adjustable thermostat be used in this test. A properly designed instrument will automatically ensure a constant temperature, and apart from an inevitable short time-lag, will correct for small alterations both in pressure and calorific value. Assuming a thermostat to be in use (see note 3f. in the Appendix *re* attachment; the Sub-Committee have invariably used one) the exact oven temperature may be readily ensured to within *plus* or *minus* 2° F., after a preliminary test to ascertain the relation between the A^b and mean temperatures.

(18) These checkings are necessary because when held at a constant temperature the oven gas-rate slowly decreases until constant conditions of heat loss are established. By taking the readings over ten minutes, small errors, due to irregularities in the meter drum, and the like, are minimized and a truer comparison obtained.

(19) See Appendix paragraph 3c.

(20) Appendix paragraph 3e.

Readings Taken

One at A = Ab_2.

Nine at B { Three at Ea = Ea_1, Ea_2, Ea_3. ,, ,, Eb = Eb_1, Eb, Eb_3. ,, ,, Ec = Ec_1, Ec_2, Ec_3. } viz.:

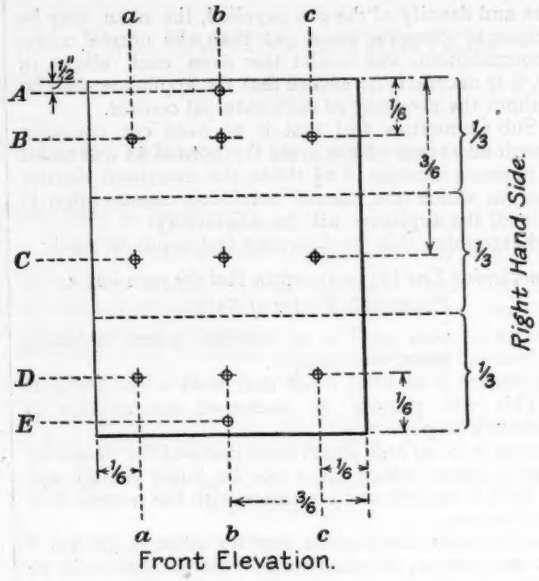
Nine at C similarly.

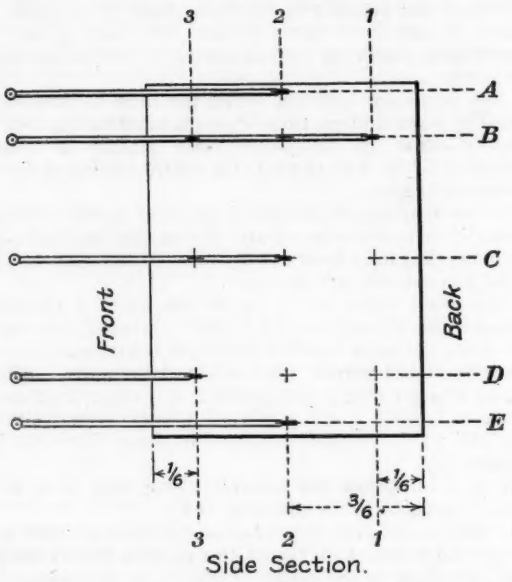
Nine at D ,,

One at E = Eb_2.

E'even thermometers.

Twenty-nine readings.





Position of Thermometers at the Start.

1 medium at Ab_2.
3 long at $Babc_1$.
3 medium at $Cabc_2$.
3 short at $Dabc_3$.
1 medium at Eb_2.

FIG. 11.—SKETCH ILLUSTRATING POSITIONS OF THERMOMETERS DURING THE "MAINTENANCE" TEST.

Provided the transfer has been properly carried out, a further set of readings may be taken at the end of seven minutes after the completion of the transfer.

After the second set of readings a second transfer is made and a third set of readings is taken. A and E are read with each set. The position of the thermometers should be checked after each transfer.

Immediately before the first set of readings the time, meter, meter temperature, meter pressure, room temperature and barometer are read and recorded, and are again subsequently read and recorded at ten or twelve-minute intervals throughout the test.

The calorimeter, which, if not in continuous use, should be started shortly after the oven is first lit up, will give the calorific value of the gas. The determination may conveniently be made immediately after the last set of meter-readings, which succeed the third set of temperature readings, in which case the collection of condensed water, on which a net value is based, should be started immediately prior to the third set of temperature readings.

At the end of all readings and determinations, the temperature record is examined, and if A and E have varied during the test the appropriate readings at B, C, and D are suitably corrected. Thereafter any individual thermometer corrections are applied. (Appendix 3d.)

The readings being now correct, all the 27 from all positions at B, C, and D are averaged and the mean represents the mean oven temperature for the purpose of this test.

From the meter readings, etc., the gas-rate, corrected to 60°F. and 30 in. saturated, is calculated and from this and the calorific value the figure for the total consumption in B.Th.U. gross per hour is obtained. The corresponding net figure should also be calculated.

Division of these last figures by the superficial area of the specified space gives figures expressed in B.Th.U. per square foot per hour, gross and net, for heat loss from the oven, at a temperature of about 370° F. above the test-room temperature.

At the conclusion of the above test the consumption rate is altered to give a mean temperature of about 320° F. above that of the test room. [21]

A period of at least 1½ hours must elapse before further readings are attempted, and it is better to allow two hours.

At the end of this period the described procedure is repeated.

After working out both results, heat loss figures are obtained in B.Th.U./sq. ft. of internal surface/ hour at two temperatures, one above and one below a rise of 350°F. above the room temperature.

By plotting these (gross and net separately) on squared paper with B.Th.U./sq. ft./hour as ordinates and rises in temperature as abscissæ, and joining the two pairs of points so plotted, the number of B.Th.U./sq. ft./hour gross and net, for a rise of 350°F. above that of the room may be read off on the curves (which are straight lines) so constructed; and the gross figure represents the comparative value of the oven for the purpose of this test. The smaller it is, the more efficient is the oven. (See fig. 9.)

[21] By adopting the device of two tests, one above and one below the actual temperature required, exactitude is gained in the final result and considerable latitude is allowed as to the temperature at which each individual test is carried out.

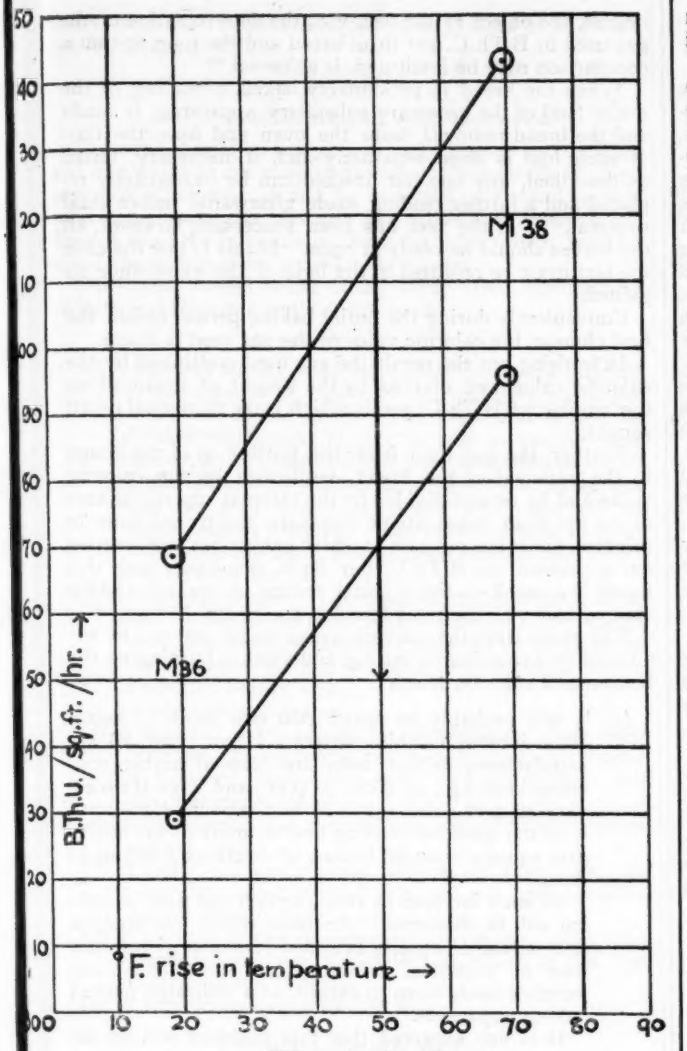


FIG. 9.—See Appendix 4c.

While recommending the gross calorific value as the basis of comparison, a matter in which the Sub-Committee apparently have no option, they would put on record that as, during a maintenance test, no steam is condensed, it is not possible to recover and use any of the heat comprised in the difference between the gross and net calorific values. Consequently the more correct basis of comparison, physically speaking, is the net calorific value.

Further, a gas-heated oven tested on the gross calorific value is debited with this difference, and will suffer in comparison with an oven heated by some other agent, which has no such disadvantage.

4.—THE SUITABILITY FOR COOKING.

So soon as solid shelves, or food, or both, are introduced into an oven, the distribution of temperature as shown by thermometer is altered.

An oven which may give excellent results in the M test may suffer from some disability when actual cooking is attempted.

A practical test is therefore necessary. [21a]

After a review of various suggestions and trials extending over several months, during which about 6 cwt. of bread was baked in eight different ovens, the Committee put forward the following procedure for assessing the comparative suitability of a number of ovens for cooking purposes.

Bread Baking Test (*Cb*).—Arrangements must first be made with a local baker for the supply of proved dough [22] in open tins. [23]

From the known volume of the cooking-space of the oven, as provided by the maker (*i.e.*, measured from the dome to the lowest runner, from the right hand gate or hanger to the left hand gate, and from the back wall to the outside face of the door-frame), [24] the weight of bread to be baked for the test is calculated at the rate of 6⅜ lbs. for each cubic foot. The appropriate quantity of dough is then provided to give this weight of baked bread. [25]

The oven under test is prepared for use by inserting the number of grid-shelves necessary to carry the tins.

It is attached to a meter and pressure gauge as laid down for the H and M tests (*q.v.*).[26] Two pressures are then predetermined by manipulation of the cock and successive one minute's observations of the meter—viz.: (*a*) That which gives the normal maximum consumption already found in H test (for use in the preliminary heating up of the oven), and (*b*) that which gives a consumption at the rate of 20 p.ct. over that already found in the M test (for use in the subsequent first baking).[27] These pressures corresponding to the respective consumptions are noted.

A thermometer is inserted at the centre hole with its bulb in the C^b_2 (central) position in the oven, in order that the temperature, at which the tins of dough are to be placed in the oven, may be ascertained.

The remaining thermometer holes are blocked by corks, although in a number of cases temperatures have been taken in an attempt to gain some knowledge of the distribution of heat during baking.

The meter being at zero and the door closed (but not luted) the cock is turned on and the gas ignited as the second hand of a watch or clock passes a given minute. [28] The pressure is immediately adjusted to that required for the normal maximum consumption. [29]

When the temperature shown by the thermometer reaches 410° F. (210° C.) the meter is read as the hand of the clock passes the nearest minute; time, meter, and temperature being all recorded. The thermometer is then removed and the tins placed rapidly in the oven as near the centre of each shelf as possible. The consumption is then altered by reference to the pressure gauge to that previously determined for the test. After this alteration, the time and meter are again immediately read and recorded, and afterwards at

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[21a] This test is carried out to discriminate between different ovens in respect of the ratio existing between the cooking space provided by the manufacturer and that actually available under varying conditions of load and temperature. The Committee realize that there is a further consideration intimately connected with the test to determine the suitability for cooking, namely, the effect on food-stuffs, more particularly of the farinaceous type, of the degree of steam saturation of the atmosphere within the oven.

Ovens may be expected to show considerable differences in this respect.

An investigation of this aspect of the question has not been attempted in the present instance, but it is well worthy of attention.

[22] It is not desirable for obvious reasons that dough should be made by other than an experienced person. By obtaining dough from a baker the quality is kept constant, which is the first essential in a series of comparative testings.

[23] There does not appear to be a universal standard size of tin for 2 lb. loaves. The local size will no doubt be found suitable for the majority of cases, and the weight of dough per tin may be varied slightly to suit the particular oven under test. The Committee have used regularly two sizes of tin—viz., 8⅜ by 4⅜ by 4¼ (known locally as "2 lb."), and 8⅜ by 4⅜ by 4¼ ("2 lb. sandwich," without the lid); they also used small tins of Turog and Hovis shapes holding 1 lb., and long tins 12¾ by 4 by 3¼ ("2 lb. long sandwich," without the lids), and had special tins made 11⅛ by 4⅜ by 4¼. The loads in all these have been varied if necessary to suit the particular oven under test.

[24] It is assumed for the baking test that this space as provided by the maker is capable of cooking.

The proportion which the cooking space bears to the total space differs in various makers' ovens. The Committee's experience leads them to doubt whether the cooking space so provided is not often an arbitrary one. The true cooking space within which food may be cooked without burning depends in internally-heated ovens on the rate of gas consumption, because the higher the rate the more space is required at the sides for the ascent of the products of combustion. The true cooking space may be expected to vary with the type of food being cooked.

[25] The Committee have no general information on this point. It may depend on the particular flour and on the quantity of water mixed with it. The mixture used in the tests has required 2 lbs. 3 ozs. of dough to yield 2 lbs. of bread or, approximately, 1·1 times bread equals dough required. As bakers must by law produce loaves of exact weight, the local baker who supplies the dough will know how much is required in his own practice to yield 2 lbs. of bread.

[26] It is much more convenient for the purpose of this test to attach the pressure gauge to the oven supply pipe at the end remote from the oven-cock. A cap will usually be found in this position. The actual pressure at the nipples is thus registered and any predetermined gas rate ensured by reference to the pressure.

[27] M test consumption in B.Th.U. per square foot per hour by 1·20 by sq.ft. of total internal surface above the teats.

The evidence collected by the Committee so far as it goes justifies the putting forward of this consumption of 20 p.ct. over the M test consumption, as a first test of the cooking capabilities of an oven. The object of the first bake is to find if possible a differentiation between the various ovens under test. With the specified consumption, loading, and procedure, an oven of better design will bake and brown its load without burning it, while one of worse design will not do so.

[28] A check of the H test may be made here by noting the time and gas required to attain a temperature of 400° F. (390°-410°).

[29] If, after previously setting the pressure by means of the cock to that required, the rubber supply-pipe from the meter be pinched instead of shutting off the gas at the cock before starting, no adjustment will be required. Loosing the rubber pipe will immediately restore the required pressure.

further intervals to ensure that the rate does not vary beyond a slight decrease which is due to the gradual heating-up of the supply-pipe and nipple.

With a loading such as indicated and at the gas-rate specified the time of baking will vary from 60 to 90 minutes. [30]

During this time it may be necessary to change the position of the tins, otherwise the bottom of the loaves higher in the oven may be underdone, while the bottoms of the lower loaves may be burned and their tops underdone. A preliminary test may be carried out to ascertain whether such change or changes are necessary. If they are found necessary, the Committee attach considerable importance to their number and to the method of carrying them out. In their opinion the fewer the changes necessary, the better the oven. There are obvious advantages to the cook in being able to leave food unattended and unwatched; at the same time, *cæteris paribus*, the fewer the changes the less gas is used, for each time the door is opened heat is lost and has to be made up for by burning more gas.

In the work, which was carried out on ovens in general use throughout the country, the Committee have found that where there are two tiers of loaves one change is sufficient, while with three tiers two changes are required, and for this test it specifies these changes as the maximum number allowable respectively. Obviously should a change in the position of the loaves in any oven prove unnecessary, this should be credited to the oven as a distinct advantage.

As to the procedure, each change consists in removing the bottom tier of loaves from the oven, moving the tiers above it one shelf down and replacing the bottom tier on the top shelf. The loaves on the right hand remain on the right, but all are reversed so that the back end comes to the front and, what is more important, the inside bottom edges and sides come to the outside, *i.e.*, into the ascending stream of hot products of combustion.

In this way, with two tiers of bread, the original top tier becomes browned on the top during the first period and on the bottom after the change; the bottom tier in the reverse order.

With three tiers, each successively occupies a position in which browning of one part or another is effected.

In other words, with two tiers each loaf occupies two positions, with three tiers, three positions, during the test.

As browning or burning either of the exposed upper surface or of the lower parts protected by the tin is, once it starts, a matter of a comparatively short time [31], the initial baking period before the first change is generally at least twice the duration of the period or periods after the change or changes.[32] It may even be more. In some cases it is not possible to brown the top tier before burning the bottom tier, and indications [33] that such is the case serve to warn the operator and also to differentiate one oven from another, for in such cases it will not be found possible to bake the bread evenly with the specified number of changes unless the consumption is reduced and a longer time taken.[34]

It must be pointed out here that the object of this test is not primarily the production of bread for exhibition purposes, but the even and sufficient baking of a batch of dough to eatable bread of a certain depth of tint. So long as the batches from all ovens under test are done to the same degree, the object of the test, viz., the determination of the gas used in B.Th.U. per lb. of bread and the time, so that a comparison may be instituted, is achieved.[35]

When the bread is presumably baked, a reading of the meter (and of the necessary subsidiary apparatus) is made and the bread removed from the oven and from the tins. If each loaf is done separately and, if necessary, tested as described, any one not finished can be immediately replaced and a further reading made afterwards before final removal.[36] If the test has been successful, however, all the loaves should be ready at once. If this is not the case the test must be repeated in the light of the experience so gained.

Conveniently during the initial baking period before the first change, the calorific value of the gas used is taken.

In working out the result, the gas used multiplied by the calorific value and divided by the weight of bread, gives the number of B.Th.U. per lb. which is the numerical result sought.

Further, the gas used from the putting in of the dough to the removal of the bread, multiplied by the calorific value and by 60 and divided by the internal superficial area of the full oven space above the teats, and by the time in minutes, gives the gas-rate at which baking has been carried on, expressed as B.Th.U. per sq.ft. per hour, and this figure is a check on the original setting of the rate and for comparison with the rates found in the H and M tests. [36]

The bread from the various ovens under test is now examined for browning on the top and signs of burning on the bottom and sides on which:

(*a*) It will probably be found that one batch is better than another in this respect. If not, and all are satisfactory, further tests are done at higher consumptions, *e.g.*, 30 p.ct., 40 p.ct., and even if necessary 50 p.ct., above the M test consumption, until with the specified loading one or more ovens fail to give equally browned loaves, while others continue to do so.

At each increase in consumption the time of baking will be shortened. An oven which will produce such a load of equally browned loaves in 45 minutes may be regarded, so far as the Committee's experience leads them to expect, as a well-nigh perfect baking apparatus.

It is not expected that this standard will be attained with so heavy a load, but by this gradual elimination of the poorer ovens there is established an order of merit which the Committee's experiments give them no reason to doubt will be reproduced on repetition; by using the specified loading a more sensitive test is obtained, a better idea of the suitability of the cooking-space provided by the maker is gained, and a higher thermal efficiency expressed in B.Th.U. per lb. shown. [37]

(*b*) Should there be, after the first test at 20 p.ct. above the M test consumption, some ovens which fail to give equally browned bread under the conditions of the test, they are re-tested at a lowered consumption and with the same general procedure.

A comparison of the results may show some ovens to be apparently equal in merit, *i.e.*, they bake their load equally in the same time. In these circumstances the best one

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[30] In present-day practice, so far as can be ascertained, 40 to 50 minutes are sufficient. There is some evidence that bread baked for (say) 80 minutes, that is, at a slower rate, is more agreeable to the palate. Questions of taste are notoriously difficult, and the Committee hesitate to make a definite statement.

[31] The baking of bread being apparently a matter of raising the general internal temperature of the loaf to just below that at which water is turned into steam. Once the surface is dry it will easily brown. Overbrowning or burning in such tests as these appears to be due to the heat being supplied to the surface of the loaf quicker than it can be absorbed and distributed through the mass beneath the surface, and this state is reached towards the end, when the surface of the loaf is dry and the temperature difference between the oven and the dough is less.

[32] Thus in a bake requiring 80 minutes the initial period from putting in the tins to the first change is at least 40 minutes, and probably 50 minutes where three tiers are being baked. This depends to some degree on the design of the oven and the placing of the burners.

[33] After a short experience the operator will be able to detect incipient burning by a peculiar acrid smell in the flue-outlet gases.

[34] During the test some indication of the correctness of the period selected for the initial baking, and, in two-change bakes, of the subsequent periods is given by the appearance of the bread at the change. At the first change the top tier loaves should be browned, but not too much, since they brown slightly afterwards. The middle tier will show few, and the bottom tier loaves probably no, signs of browning at all. At the second change, should experience suggest that the previous periods have been too prolonged, the last period may be shortened.

[35] It may be stated that the outside appearance of a loaf is not a complete criterion of the state of the inside, since browning can be made a matter of a few minutes only. Various tests of baked loaves are put forward, such as rapping the crust sharply with the knuckle, when a slight crackling should be audible. The only one the Committee finds used by practical bakers (apart from the supreme test of eating the bread) is to push the thumb against the surface of the suspected part without puncturing it. If the part so treated returns to its original outline the bread is baked. If on the other hand a permanent depression is caused it is underdone.

A further confirmation of baking lies in the weight of the *cold* loaf. This, however, depends on the correct weight and invariable composition of the original dough. Under the present law, as already mentioned, a 2-lb. loaf must weigh 2 lbs., and the baker cannot afford to risk underweight. To make a weight test effective, the weight of the original dough would have to be checked.

A 2-lb. loaf hot from the oven will lose approximately ¼ to ½ oz. in weight after standing for half-an-hour.

[36] The rates are expressed in B.Th.U. per lb. and in B.Th.U. per sq. ft. of surface per hour to enable comparisons to be made between the results from different sizes of ovens.

[37] The extreme opposite, viz., the baking of one single loaf in each oven whatever the size, would manifestly give:

1. A high figure for B.Th.U. per lb.
2. A better figure for a small oven,

thus entirely masking the true result.

is that with the lowest consumption expressed in B.Th.U. per lb. of bread. [38] [39]

APPENDIX.

1.—Conditions Making for Accuracy.

The oven should be tested in as large a room as possible, and one which is not subject to violent fluctuations of temperature. The oven should be mounted on a stand, with a solid upper surface at least one foot above the floor, to withdraw it from the influence of floor draughts which tend to affect the results in an incalculable manner.

The oven should stand freely away from surrounding objects and from the walls of the room.

2.—Apparatus Required.

(*a*) A test wet meter, with the spindle connected directly to the large index figure, of not less than ½ c.ft. per revolution of the drum. The main dial should be divided into tenths of a c.ft. and so marked and figured, and further marked into hundredths of a c.ft. These last marks will not be absolutely accurate, but may be read where necessary and regarded as approximately correct. The meter should be provided with the usual thermometer, plumb bob, levelling screws, &c.

(*b*) A pressure gauge. The small Committee have used, and found convenient, King's gauges. The gauge must, however, be capable of showing up to 2½ times the minimum district pressure as prescribed in the Factor of Safety Test.

(*c*) An adjustable governor.

(*d*) A shielded thermometer for ascertaining room temperature. The shield is conveniently a hollow cylinder of polished metal suspended co-axially about the thermometer bulb.

(*e*) A calorimeter for ascertaining the calorific value of the gas used.

(*f*) A test clock reading one minute per revolution, the main dial being divided into seconds and a smaller dial showing minutes up to at least 30.

(*g*) A number of thermometers for ascertaining oven temperatures (as per Schedule mentioned in the test describing the M test).

(*h*) A thermostat (see under M test).

3.—Preliminary Work.

(*a*) The dimensions of the oven under test are to be ascertained and noted as per schedule as follows:

Schedule of Dimensions.

a	Side to side.
a, *b*, *c*	Back to front (outside surface of door frame).
a	Teats to underside of dome (internal crown plate).
b	Distance between the gates (hangers).
b	Door-sill to first runner (grid support).
c	Door-sill to teats.
c	Door-opening, — high, — wide.
c	Distance underside of dome is above or below edge of door frame.
c	Door, — high, — wide, overlap on frame.
	Teats to drip tin —.
	Number of runners —.
	„ „ shelves, — wide, — deep.
	„ „ grids, — wide, — deep.
	„ „ teats on each burner — drilling.
	Projection of teats from oven sides.
	Distance of nearest end teat from front — , from back —.
	Slot in dome, — wide, — deep.
	Flue-outlet (internal sizes), — wide, — deep; area, — sq. in.

From those marked "*a*," the total oven volume is determined in cubic feet and the total internal area in square feet.

From those marked "*b*," the volume and area of the cooking space provided by the maker.

From those marked "*c*," the position on the door of the holes through which the thermometers are to be inserted and the depth of insertion.

From those unmarked much useful comparative information is given.

The door-sill is used as a datum line in some measurements on account of its convenience.

(*b*) If the oven contains two burners they should be tested to see if they pass equal quantities of gas per hour as received. If they do not, the results should be noted. Unequal rates affect the H, S, and M tests adversely, and also cause overheating and burning of the bread on one side of the Cb test.

(*c*) The oven door must be marked out accurately at the points where thermometers are to be inserted. These points are settled with reference to the space to be explored and not primarily with reference to the door. The appropriate points on the door must be settled with reference to this space. After marking out the positions, holes are drilled with a $\frac{5}{16}$-in. twist drill through the door casting and right through the enamelled door back, where fitted; care being taken that the drill is at right angles to the surface of the door, otherwise the thermometer bulbs will not reach their correct positions inside the oven space.

The hole in the casting, and *not* that in the enamelled door back, is then enlarged with a $\frac{5}{8}$-in. drill.

The $\frac{5}{8}$-in. hole takes a "5-light meter cork," which is $\frac{5}{8}$ in. at the smaller and $\frac{3}{4}$ in. at the larger end, and through which a thermometer is passed after boring a suitable hole with a rat-tail file. The $\frac{5}{16}$-in. hole in the door plate is large enough to pass the thermometer and to act as a guide and support for it; the stem should no more than clear the hole, thus allowing no possibility of leakage.

(*d*) All the thermometers (unless provided with calibration certificates) require comparison and standardization before being accepted for use. (The Small Committee have found differences up to 10-12° F. in the readings of thermometers from the same batch.) In checking, immersion in heated oil of high flash-point is recommended. The thermometers should be compared with their stems immersed to the depth at which they will be used in the oven, otherwise errors are introduced. [22]

All thermometers must be of the type having the thread channel enlarged to a bulb at the upper end. Before first use each thermometer should be cautiously heated over a small flame until the thread rises part way into the bulb. It has been found that this, together with the method of inserting through a cork, greatly minimizes the tendency for the thread to break and thus spoil the readings.

(*e*) Before use with any particular oven each thermometer, which must have a distinguishing number, is measured to ascertain which graduation on the stem should appear level with the visible end of the supporting cork when the longitudinal centre of the bulb is in its exact position in the oven. A record is kept of this information, and the verification of the position during the test, particularly after each change of vertical position, is thus greatly facilitated.

(*f*) The thermostat used by the Sub-Committee is of the expanding tube and non-expanding rod type. It is conveniently inserted at the top of the oven through a hole drilled in the door similar to those through which the thermometers are inserted. The hole would correspond to the A^a or to the A^e position, whichever is nearer to the hinges according as the

[38] For reasons discussed in another part of this Report (Appendix 7) the order of merit of ovens as determined by the Cb test may not necessarily be exactly the same as that discovered in the M test, but, with the type of ovens tested, it is substantially the same.

Illustrating the above remarks and also former ones on the increased sensitiveness of the test when made with heavy loads, the example of ovens C1 and C2 may be quoted. These are identical in all but flue area.

Their M test results are respectively 559 and 456 B.Th.U. per sq. ft. per hour, and their Cb tests with full load are 1041 and 935 B.Th.U. per lb., while with two-thirds full load they are 1311 and 1316 B.Th.U. per lb.

The saving on the M test is 18·5 p.ct., and on the full Cb test 10·4 p.ct., while with the lighter load there is no differentiation.

[39] The Cb test affords data as to gas, time, and evenness of baking. The Committee's suggested use of these for the purpose of determining an order of merit might conceivably be modified to suit particular cases. For instance, where gas is dear more attention might be given to the gas result than to the time result. Where it is cheap a saving of time might be more valuable than a saving of gas. Considerations of this sort and their influence must be left to the decision of the responsible official concerned.

As already remarked, the Committee do not anticipate that ordinary ovens bearing the specified load will be workable with fewer than the specified number of changes. Should there be ovens in which this load could be baked with fewer changes, another factor of merit would be introduced and its influence would have to be allowed for.

[22] If the tests are approved, arrangements for the supply of sets of suitable thermometers, calibrated and checked as above, may probably be possible with thermometer makers. The Sub-Committee would be prepared to draw up a specification based on their experience.

door opens from right to left or *vice versâ*; fixed in this way the door may be opened without withdrawing the thermostat from it.

4.—EXAMPLES OF TESTS.

(*a*) *Example of a Heating-up Test.*

Date, 1st January, 1924. Cooker C.
No. H40. Gas pressure, 12½-10ths.* Temperature, 61° Fahr.
Bar., 30·2 in. Cal. val., 492·2.

Time.	Meter.	Cb_2.†	Room Temp.	—
..	..	18·5	18·5	
1.0	0·32	90		
2.0	·63	123		
3.0	·97	142		
4.0	1·29	153		Internal superficial area, 12·10 sq.ft.
5.0	·62	162		Rate, 19 69 c.ft./hour.
6.0	·95	169		,, =9692 B.Th.U./hour.
7.0	2·28	175		,, =801 B.Th.U./sq.ft./hour.
8.0	·61	181		Time to reach 400° Fahr. (204° C.) 13 minutes.
9.0	·94	186		
10.0	3·26	191		
11 0	60	195		
12.0	·93	200		
13.0	4·25	203		
14.0	·59	207		
15.0	·92	209	19·2	
15.14.4	5 00	..	..	

(*b*) *Example of a Smothering Test.*

Date, 11th December, 1923. Cooker D. Number S. 18.
The pressure at which the cooker heated up to 400° Fahr. in the specified time was 12½/10ths* and 12·5 × 2·5 = 31¼/10ths.
At 37/10ths left hand flames stagger and lengthen and several leave the burner.
At 35 do. do.
At 33 no flames leave the burner.
The oven just passes the test.

* These tests were made with the nipples as supplied by the makers. In practice they would have to be adjusted to give the same consumption of gas "at 20/10ths or the minimum pressure on the district, whichever is the higher," as laid down in the text describing the H test.

† The actual observed temperatures are given in Centigrade degrees as the Committee found it easier to get Centigrade than Fahrenheit thermometers at the time they wished to start work. The meters were, however, provided with Fahrenheit thermometers.

5.—NOTES ON FLOATING AND SMOTHERING.

It is not easy to define the above terms accurately.

The Sub-Committee make the following observations to assist those who are not familiar with this class of work. When gas is burned from an "atmospheric" burner under conditions such that sufficient air is not immediately available for complete combustion, the flame lengthens and loses shape. Where there are a number of flames close each to others as in an oven burner, the result is a sheet of flame, often without any defined inner cones. This simple case occurs in some ovens, but more often the matter is complicated by the products of combustion circulating within the oven space, returning to the flame level and there impinging on the existing flames. This gives rise to what may be called floating, where the flames at some part of their length are nearly extinguished, but surviving, pass on to a region richer in oxygen and so re-appear and possibly more or less complete their combustion. In some ovens the impingement of burned products on to the flames is intermittent, owing to the direction of circulation being unsteady. In such cases one or more flames may become intermittently extinguished, and a blank space appear at the teat or teats affected; they return however to their teats. When this alternate extinguishing and relighting of several flames takes place rapidly, the Sub-Committee have found it convenient to refer to it as "staggering."

As the gas rate is increased, by increasing the pressure, this condition worsens and eventually, one or more flames become permanently extinguished at the teats of one or both burners. When this state is arrived at the Sub-Committee consider it a definite indication that safety is questionable, for a slight further increase in pressure is usually enough to cause the complete extinguishing of one burner. The Sub-Committee have therefore recommended this state as a working definition of smothering.

Unequal consumption of gas as between the two oven burners usually causes this state to appear sooner, and on the burner with the lower consumption, for the more power-

APPENDIX 4 (*c*).—*Example of a Maintenance Test.*

Date: 19th November, 1923. COOKER E.
Number M 36 and M 38. M 36 at low temperature. Thermostat at Mark 6·2. A and E varied 1° C.

Corrected Temperatures.

—	A.	a.	b.	c.	E.
B—					
1 . . .	194	201	197½	202½	177
2 . . .	..	193½	194½	200	..
3 . . .	..	184	188	184	..
Mean of all B = 193·9					
C—					
1 . . .	..	198½	196½	196½	..
2 . . .	..	198	192½	204½	..
3 . . .	..	185	187	184	..
Mean of all C = 193·6					
D—					
1 . . .	..	191½	192	191	..
2 . . .	..	197	184½	197	..
3 . . .	..	183	180½	183	..
Mean of all D = 188·8					
Mean of a = 192·4 b = 190·3 c = 193·6					
GRAND MEAN = 192·1					

Gas Readings.

Time.	Meter.	Rate C.Ft./Hour.	Meter. Temperature.	Meter. Pressure.	Room Temperature.	Barometer.
				Tenths W.G.	c° C.	In.
11.26	73·10	..	59	21	15	29·62
·36	75·99	17 34	58·8	21	14·9	temperature readings start
·46	78·84	17·10	58·8	21	14·9	
·56	81·69	17·10	58·8	21	15·0	..
Mean from "start"	..	17·10	58·8	21	15	29·62
Corrected to 60 in. and 30 in. moist		17·02	Cal. Val. 483·8 gross.		431·0 net B.Th.U.	

B.Th.U. used, 8236 gross = 369 B.Th.U. per sq. ft.
7338 net = 329 ,, ,, ,,

Rise above room, 192·1 − 15·0 = 177·1° C. = 318·7° F.

M 38 at high temperature. Thermostat at Mark 8·9. A and E varied 1½° C.

—	A.	a.	b.	c.	E.
B—					
1 . . .	224½	231	228	234½	201½
2 . . .	..	224	224	230	..
3 . . .	..	213	217	211½	..
Mean of all B = 223·7					
C—					
1 . . .	..	229	226½	228½	..
2 . . .	..	230	220	236	..
3 . . .	..	211½	213½	210	..
Mean of all C = 222·8					
D—					
1 . . .	..	219½	220	221	..
2 . . .	..	230	211	230½	..
3 . . .	..	209	207	208½	..
Mean of all D = 217·4					
Mean of a = 221·9 b = 218·6 c = 223·4					
GRAND MEAN = 221·3					

Time.	Meter.	Rate C.Ft./Hour.	Meter. Temperature.	Meter. Pressure.	Room Temperature.	Barometer.
				Tenths W.G.	c° C.	In.
3.25	22·23	..	59·5	20	16·1	29·62
·35	25·61	20·28	59·5	20	16·1	temperature readings start
·45	28·95	20·04	59·5	20	16·1	
·55	32·25	19·8	59·5	20	16·1	..
Mean from "start"	..	19·92	59·5	20	16·1	29·62
Corrected to 60 in. and 30 in.		19·79	Cal. Val. 499·3 gross.		447·3 net B.Th.U.	

B.Th.U. used, 9881 gross = 443 B.Th.U. per sq. ft.
8832 net = 396 ,, ,, ,,

Rise above room, 221·3 − 16·1 = 205·2° C. = 369·4° F.

APPENDIX 4 (*c*).—*Example of a Maintenance Test (continued).*

(Summary of Figures from the above Maintenance Test.)

—	M. 36. °C. &c.	M. 36. °F. &c.	M. 38. °C. &c.	M. 38. °F. &c.
Means of horizontal planes—				
All B (9)	193·9	381·0	223·7	434·7
C	193·6	380·5	222·8	433·0
D	188·8	371·8	217·4	423·3
Means of vertical planes—				
All *a* (9)	192·4	378·3	221·9	431·4
b	190·3	374·5	218·6	425·5
c	193·6	380·5	223·4	434·1
Reading at Eb_2	177	350·6	201·5	394·7
,, Ab_2	194	381·2	224·5	436·1
Grand mean (27) = oven temperature	192·1	377·8	221·3	430·3
room ,,	15·0	59·0	16·1	61·0
rise	177·1	318·8	205·2	369·3
Total heat units used per hour . . . gross	2075·6	8236·0	2490·1	9880·8
,, ,, ,, ,, . . . net	1849·3	7337·8	2225·7	8831·8
Heat units/sq.ft./hour for full area of the oven . . . gross	93·0	369·1	111·6	442·8
,, ,, ,, ,, ,, . . . net	82·9	328·9	99·7	395·9
,, ,, ,, for "cooking space" as provided by the maker . gross	118·2	469·3	141·9	563·1
,, ,, ,, ,, ,, ,, ,, ,, . net	105·4	418·2	126·9	503·4
Heat units/sq.ft./hour for a rise of 194·4° C., 350° F. for full area (from curves, fig. 9). gross			K.C.U. 164·6	415 B.Th.U.
,, ,, ,, ,, ,, ,, ,, ,, . net			147·0	370·51

(N.B.—The preparation of such summaries brings out a number of facts more clearly than the more extended original readings —*e.g.*, the relation of Ab_2 to grand mean, the temperature equality, or the reverse, at various levels and from sides to centre. Burners passing unequal quantities of gas give quite different results.)

APPENDIX 4 (*d*).—*Example of a Bread Baking Test.*

Date: 21st March, 1924. Oven C2 3 tiers, 6 loaves each in 2 lb. "Sandwich" tins = 12 lbs. of bread.
No. Cb 37 (as Cb 26 but rate reduced to 8½/10ths pressure).

Time.	Meter.	Rate.	—	Temperature.	Pressure.
9.56	*Nil*	..	Confirmatory heating-up	Cb_2 19° C.	13/10
10.08	4·28	21·4	Test, H.97	203	
10.10	4·96	..	Dough in	211	8½/10
10 25	9·05	16·36	..	Ab_2 146 Cb_2 93 Db_2 ..	..
10.35	11·67	15·72	..	152 102 101	..
10 45	14·26	15·54	..	158 112 109	..
10.55	16·88	15·72	..	165 122 119	..
11.00	18·19	15·72	1st change (50 minutes)	166 127 126	..
11.10	20·70	15·06	2nd ,, (10 ,,)	170 149 132	..
11.20	23·24	15·24	All out (10 ,,)	174 137 139	..
11.40	..	..	Empty for 20 minutes	228 233 219	..

Meter temperature, 61° F. Room temperature, 17° C. (62½° F.). Barometer, 29·7 in.

Total gas . . . . . 23·24 c.ft. = 11,210 B.Th.U. = 934·6 B.Th.U./lb.
Gas during cooking . . 18·28 ,, (= 8,822 ,, = 735·2 ,, ,,) Initial temperature, 211° C. Time, 70 minutes.
Rate during cooking . . 15·67 c.ft./hr. = 7,563 B.Th.U./hr. = 625 B.Th.U./sq. ft., at 8½/10 pressure.
H.97 . . . . . 203°—19° in 12 minutes for 21·40 c.ft./hr. = 10,330 B.Th.U./hr. = 853 5 B.Th.U./sq. ft./hr., 13/10 pressure.

Remarks.—Bread good, but those starting on bottom grid and finishing in the middle one were slightly burned at one edge, indicating that the initial period of 50 minutes was too long.

N.B.—In this case the thermometer bulbs were disposed:
Ab_2 above the top tier.
Cb_2 between the tins on the middle grid.
Db_2 ,, ,, ,, bottom ,,

A sudden rise after a change is probably due to the reversal of the tins and the consequent proximity of the hotter side to the thermometer bulb.

ful upthrust of products from the burner with the higher consumption forces them below the level of the former.

Where burners are adjusted to consume equal gas, the one at which the gas is first ignited usually prevails over the other.

In some cases burners alternately prevail one over the other as some slight deflection of the stream of products gives one or other the advantage.

Actually, should one burner become completely extinguished and continue to add its quota of gas and air to products of combustion from the other, the resultant mixture is not combustible, otherwise it would be burned inside the oven, which is not the case. There is, however, the possibility that such a mixture may become combustible when it issues from the flue-outlet and mixes with the air.

APPENDIX 6.

Several alternatives are open in suggesting a test that is before all a practical test made as "scientific" as possible, and not a "scientific" test made as practical as possible.

1. A definite time of baking may be specified and the bread loaf varied; this will also entail varying the gas.
2. A definite consumption may be specified and the load and time varied.
3. A definite load may be specified and the time and gas varied.

The question then arises as to which of the variables under each heading is the easiest to assess in employing the results for determining the order of merit of the ovens.

The Committee reject No. 1, because, although a time of 45-50 minutes is common practice, it will, so far as the experiments go, entail a smaller load than the arrangements of the maker for cooking space make possible. With a smaller load the test is not so sensitive in differentiation between ovens. (See footnote 38.)

It may also be remarked that there is no fundamental reason why 45-50 minutes should be regarded as a fixed and unalterable time for baking bread. The proof of the bread is in the eating, and, as indicated elsewhere, there is some ground for thinking slowly baked bread is more palatable.

The Committee reject No. 2 because definite consumption referred to any physical dimension of the oven is incapable of giving the same mean temperature in different ovens owing to their difference in lagging and in flue-outlet area, and further because here again the load would have to be varied.

The Committee adopt No. 3 because, if the arrangements of the maker for cooking space (by which is meant not only the proportion of total space but its position in the total space, and also the arrangement of the burners and flue-outlets with regard to it) are well conceived, the oven will show a higher figure of merit than one in which the maker's arrangements for cooking space are not so well conceived.

The Committee, in fact, base their practical baking test primarily on the cooking space as provided by the maker.

APPENDIX 7.

It has been suggested that a relationship or nexus could be determined between the various tests put forward. Closer consideration, however, will show that there is no particular fundamental reason why there should be a definite relationship.

The H Test depends to a large extent on the mass of the oven. It is a much more empirical test than the M Test. It also depends, of course, on the actual flue space, intended and adventitious. The M Test, while also considerably affected by the flue space, is primarily intended as a measure of heat insulation, and its result is expressed with reference to superficial area.

The S Test depends neither on mass nor insulation, but on flue space, restriction of the inlet air if provided, and to some extent on the disposition of the fittings and internal flue spaces inside the oven. It is empirically related to the H Test by pressure.

The Cb Test, so far as its result in heat units per lb. of bread is concerned, depends mostly on the weight of dough, which represents a cubical quantity, and to a small extent on the mass of the oven and on the insulation. No definite relationship is to be expected for different sized ovens between results calculated on superficial area and those calculated on cubical volume, since with rectangular volumes like ovens, the area increases approximately as the square, and the volume approximately as the cube of the basic linear increase.

Again, as the temperature distribution is altered when solid bodies are introduced into an oven, the heat loss figure may then be slightly different.

Further, since in actual baking we are concerned with the absorption of heat by dough, the increased thermal efficiency shown in an M Test by making addition to the insulating material or by altering the flue outlet cannot be reflected entirely in the baking figure. To make the point clear, take the extreme case and suppose we had perfect insulation, no gas would be required to maintain the temperature; if now dough were introduced, the temperature would immediately begin to drop, until equilibrium was attained between dough and oven, but the final temperature so attained would be low and cooking would not proceed. Insulation would be 100 per cent. effective; baking, *nil.*

Any correspondence between M and Cb Test figures would tend to become less and less the more perfect the insulation, *i.e.*, the better the M Test figure.

APPENDIX 8.

In considering various proposed oven tests put before them, and in finally recommending those described in the Report, the members of the Committee have kept in mind the following questions, to which in their opinion any test or tests must supply answers before being considered satisfactory. These questions are in fact such as would inevitably occur to the mind of any prospective or intelligent purchaser of a gas-oven.

1. Does the oven smother?
2. Does the oven consume sufficient gas to cook in a reasonable time?
3. Is the distribution of heat sufficiently uniform to allow of a full load of food being cooked with the least number of changes of position of the food. If not, how many changes are necessary to avoid burning?
4. Is the oven economical in gas consumption?
5. What percentage of the total space of the oven is available for cooking?
6. Does the oven heat-up in a reasonable time?
7. Is the oven as efficient when used quickly as when used more slowly?

The tests put forward supply answers to all these questions.

The Committee have; moreover, kept in view the undermentioned points with which an ideal test should conform so far as possible.

8. The results must be reproducible.
9. The results of physical tests of ovens of the same construction (lagging, proportion of flue-area, &c.), but of different sizes, should agree, and therefore results from ovens of different construction should be comparable whatever the size.
10. The test or tests should be as simple as possible in:
    (*a*) Apparatus required.
    (*b*) Application to the oven.
    (*c*) Calculation of results.
11. The results should be in readily understandable units.
12. The results should bear some relation to practical fitness for cooking.

APPENDIX 9.

The reliability of temperature readings taken in an oven.

It has been suggested that thermometric methods of testing ovens suffer some disability that invalidates the results based on them.

So far as the Committee's experience with gas-heated ovens goes, no justification can be found for this view. Were it otherwise, no test on the lines of the present M test would have been put forward.

Results from one oven are reproducible with a remarkable degree of exactitude; results from different ovens of the same construction agree very well; while results from ovens of diverse construction are in accordance with the expectation raised by general consideration.

(1) A specific question to which the Committee gave early attention was that concerned with the use of ordinary mercury-in-glass thermometers. Do these, owing to their reflecting powers and to the possible proportion of heat transferred by radiation from the walls of the oven, give low readings compared with black-bulb thermometers?

To test the point an M test was made, in which two sets of thermometers, one with bright and the other with blacked bulbs (previously compared in heated oil), were used. Two sets of readings were thus obtained. At each hole in the door the three back to front readings were taken successively with the bright and black bulbed instruments. At different levels bright and black might be in simultaneous use. The possibility of error was thus reduced compared with the alternative of doing two complete separate tests, one with each sort of thermometer.

The mean oven temperatures so determined were

Bright bulbs 211·9° C. (413·4)
Black ,, 212·6·° C. (414·7)
Difference 0·7° C. (1·3° Fahr.)

This disposes of any fear of results being vitiated from the cause suggested.

(2) In Appendix 8 (Nos. 8 and 9), two of the points mentioned as being kept in view in designing a test are that results shall be reproducible, and that results from different sized ovens of the same construction should agree. The Committee gave no small attention to this latter condition. It was considered that if tests of ovens of the same construction but different size did not agree, the test could not be recommended for acceptance. As the temperature readings are the basis of the test, a short account of a crucial experiment may be included in this section of the Appendix. Oven C and Oven E from a series of cookers of similar construction were selected for test. It appears obvious that if their flue outlets are not proportional to their internal superficial area, their results will not agree. It was found that the superficial areas were 12·10 and 22·31 sq. ft. respectively, whereas their flue areas were 5·52 and 5·14 sq. in. To correct this a cap was made, and the flue outlet of oven C reduced to 2·78 sq. in.

Under these conditions the tests showed:

—	Oven C.		Oven E.	
	°C.	° Fahr.	°C.	° Fahr.
Mean temperature	213·9	417·0	211·8	413·2
Room	20·7	69·3	20·0	68·0
Rise	193·2	347·7	191·8	345·2
Heat units/sq.ft. gross	118·7	470·8	104·1	413·0

Difference—14·6 K.C.U., or 57·8 B.Th.U./sq.ft./hour.

This difference in favour of the oven E appeared to be too great to attribute to experimental error and/or to the slight difference in the rise maintained. Had no other explanation been possible, the difference would have been sufficient in the Committee's opinion to have invalidated the form of test.

An examination of the cookers in detail showed the oven E to be provided with greater thicknesses of packing, which varied on the sides, the back, and the door.

Assuming for slag-wool a loss, as given by Kaye and Laby, of 0·26 K.C.U. per hour per sq. ft. per in. thick per 1° C. difference of temperature, and calculating on the thicknesses found and an internal temperature of 200° C., a differ-

ence of 8·3 was accounted for out of a total difference found of 14·6 K.C.U.

[Another authority gives 0·36 K.C.U. as the loss, which would bring the calculated losses to a difference of 11·5.]

In an attempt to minimize that part of the difference which might be due to the different rises maintained in the above tests, a further pair of tests was made, with the following result:

—	Oven C.		Oven E.	
	° C.	° Fahr.	° C.	° Fahr.
Mean temperature	202·3	396·1	202·9	397·2
Room	22·8	73·0	21·9	71·4
Rise	179·5	323·1	181·0	325·8
Heat units/sq.ft./hour	109·4	434 1	99·3	394·2

Difference—10·1 K.C.U., or 39·9 B.Th.U./sq.ft./hour.

As already shown, the calculated difference for the two ovens is 8·3 K.C.U./sq.ft. at 200° C., leaving less than 2 K.C.U. unaccounted for. In the Committee's opinion this is a very satisfactory result and one within the possible error of experiment.

[It is necessary to remark that these tests were made at an early stage, before the device of taking two tests, constructing a curve, and interpolating for a definite rise, as now laid down in the M test directions, had been decided on.]

APPENDIX 10.

Notes on the possible reduction in the number of thermometer readings during the M test.

1. Before adopting the scheme of readings laid down in the Report, the Committee made experiments with a larger number; they also compared the means of various groups of temperatures taken from the full number, in an attempt to simplify the test. It had been hoped that some one reading or mean of one or two readings might be found that should represent the mean of all the readings. This hope so far has not been fulfilled. The most that has been possible has been the reduction of the number of readings from 125 (which was the number taken in the first form of M test) to 27.

In spite of the failure of the attempt to reduce the number of readings, on which the mean oven temperature is based, to fewer than 27, it has been found that the top check reading at A^b_2 is always very close to the mean oven temperature, and that, while it differs from the latter to a greater or less degree in different ovens, yet in the same oven the difference is nearly constant. This relation of the A^b_2 temperature to the mean oven temperature is not sufficiently constant to justify the use of the former as a substitute for the latter, but once the difference between them has been found for any oven by experiment, the A^b_2 reading becomes a useful indication by which to set the rate, when any particular mean oven temperature is desired.

2. A further attempt to simplify the procedure took the form of using a thermometer with a bulb extending over the depth previously explored by using three short bulb instruments in succession at the positions 1, 2, and 3. If successful this would reduce the number of individual readings taken in each M test from 27 to 9.

A series of duplicate M tests was made, using both long and short bulb thermometers successively in six ovens. The high and low temperatures maintained in each gave twelve comparisons.

Taking the mean oven temperatures so obtained, the long-bulb thermometers gave consistently slightly higher results than the short-bulb—maximum difference 3·8° C.; minimum 0·9° C.; mean of all 2·2° C. This may have been due in part to fundamental disagreement between thermometers, as the long-bulb ones had not been tested for accuracy.

Taking the two differences in each pair of tests (high and low temperature), the greatest divergence between the one and the other was 1·5, and the least 0·1. The average effect of these divergencies on the result of the M test is not more than 8 B.Th.U. per sq. ft. per hour, and this is of little practical importance. Using three long-bulb thermometers, however, their effect on the duration of the test is confined to the short time saved in taking three readings at each level instead of nine (which is very little when it is remembered that at least seven minutes must elapse after shifting them from one level to the next, before further readings may be taken), and the short time further saved in averaging during the working out of the results.

If nine long-bulb thermometers were used no shifting of level would be necessary, all the readings would be obtained one after another to the number of nine, and no correction for possible rise or fall in the check thermometers would be necessary.

Taking into account the fragility of these long-bulb thermometers, their price, and their limited applicability to any other work, their use would be beneficial only if fairly regular testing were in contemplation, and then only if nine were used.

APPENDIX 11.

Effect of introducing solid shelves into the oven.

1. Effect on the temperature distribution:

Oven C fitted with a door drilled with holes at five levels. As a door already drilled had to be utilized, the vertical position of these levels was not the same with regard to the nearest shelf. The positions of the various levels was actually as follows:

Level*	A (the same as A in the M test)				
N	5⅛	above shelf X	on the	5th	runner.
O	1¼	" "	Y	3rd	"
P	2⅝	" "	Z	1st	"
Q	2½	below	Z	1st	"

* The levels are as in Appendix 12.

APPENDIX 11.* 1.—*Table of Mean Temperatures.*

—	M 27a. No Shelves.		M 27b. 3 Shelves. X Y Z.		M 27c. 2 Shelves. X Y.		M 27d. 1 Shelf. X.		M 28a. X 1 Full Shelf. Y_2 1 Medium. Z_2 1 Small.		M 28b. XY 2 Full Shelves. Z_2 1 Medium.		—
	° C.	° Fahr.	° C.	° Fahr.	° C.	° Fahr.	° C.	° Fahr.	° C.	° Fahr.	° C.	° Fahr.	
Mean of A (9)	205·2	401·4	196·8	386·2	195·2	383·4	198·7	389·7	193·8	380·8	191·6	376·9	
N	206·7	404·1	192·8	379·0	192·0	377·6	196·4	385·5	187·6	369·7	185·4	365·7	Level of shelf X
O	205·4	401·7	213·5	416·3	212·8	415·0	222·5	432·5	204·7	400·5	204·0	399·2	" " Y
P	195·8	384·4	230·0	446·0	228·8	443·8	210·9	411·6	216·2	421·2	217·6	423·7	" " Z
Q	177·3	351·1	209·2	408·6	196·2	385·2	186·9	368·4	175·4	347·7	181·9	359·4	
All (45)	198·1	388·6	208 5	407·3	205 0	401·0	203·1	397·6	195·5	383·9	196·1	385·0	
All, *less* Q (36)*	203 3	397·9	..	..	..	..	..	..	..	..	..	..	
$A_2{}^v$ (uncorrected check)†	197·5	387·5	196·5	385·7	191·0	375·8	185·5	365·9	187·5	369·5	187·5	369·5	
Mean at Ab_2 Bb_2, &c. (5)‡	197·1	386·8	213·8	416·8	205·9	402·6	202·1	395·8	197·0	386·6	194·5	382·1	
Room	21·3	70·3	21·0	69·8	20·7	69·3	20 5	68·9	14·7	58·5	15·2	59·4	
Heat units/hour gross	1383	5486	1430	5676	1402	5563	1411	5597	1376	5460	1377	5462	
= C.Ft. at 500 B.Th.U.	..	10·97	..	11 35	..	11·13	..	11·19	..	10·92	..	10·92	

* This would correspond approximately to the mean as found by the 27 readings usually employed. † Not Ab_2 which is usually from 7° C. to 14° C. higher than the position called above $A_2{}^v$. ‡ The centre readings at each level.

Three sizes of shelf were used:

X Y Z, or full size, viz.,	$12\frac{3}{8} \times 11\frac{3}{4}$ slotted at the sides *
Y_2 and Z_2	$9\frac{3}{4} \times 11\frac{3}{4}$
Z_3	$7\frac{1}{4} \times 11\frac{3}{4}$

* There were two slots at each side, each 4 in. by ½ in. and 1 in. from the edge.

The procedure: The oven was heated up with thermostat in use until constant temperature was established. An M test was then carried out (M 27a) using 45 temperature readings—*i.e.*, five levels three holes at each level, and three readings at each hole. On the completion of this test, the three full-sized shelves were introduced as above. As shelves interfere with the action of the thermostat, this was then by-passed and the gas supplied to the oven at a governed pressure corresponding to that already established by the thermostat.

After a suitable interval a further set of temperatures was taken (M 27b).

Subsequently two further sets were taken with shelf Z removed (M 27c) and with shelves Y and Z removed (M 27d).

Further tests were made afterwards, in which shelves X, Y_2, and Z_3 (M 28a) and shelves X, Y, and Z_2 were used (M 28b).

The results are best shown in parallel columns (see Table).

It will be seen that governing does not keep the consumption constant, nor does it exert control to compensate for any alteration in calorific value. All the same it is remarkable that the mean of all readings should apparently so clearly reflect the alteration in the gas rate despite the shelf alterations. The means of the various levels are in accordance with expectation—the temperature backing-up below each shelf.

2. Effect on the flue outlet gases:

It was suggested that the placing of solid shelves or tins containing food, or the like, in an oven might so interfere with the circulation and discharge of products of combustion as to constitute in effect a restriction at the flue outlet.

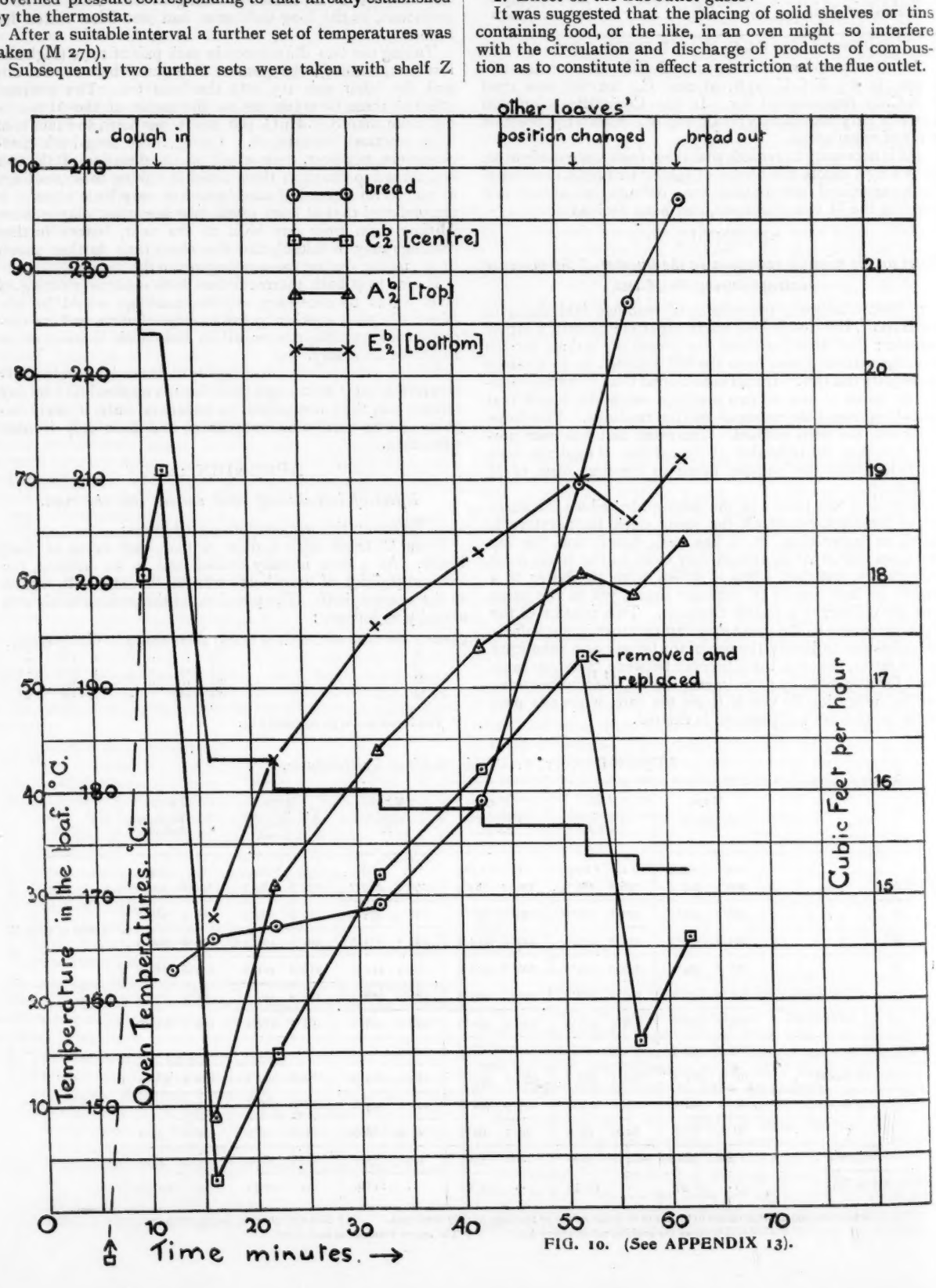


FIG. 10. (See APPENDIX 13).

To investigate this point a series of air samples were taken from the flue outlet of an oven with and without three shelves. Analysis of the samples (for which the committee had no apparatus), was carried out by Mr. J. G. Clark, one of its members.

The results showed that there was little difference in the amount of air over and above that required for combustion, found at the flue outlet, the calculation showing 417·5 c.ft. of air per hour with no shelves and 379 c.ft. per hour with three shelves, or approximately 32 and 29 c.ft. of extra air per c.ft. of gas burned respectively.

Contrasted with this, the effect of blocking the flue from full size to approximately half-size caused a reduction in the extra air from 390 to 253½ c.ft. at the same gas consumption (the temperature at the top of the oven rising 26° C. (47° Fahr.)), and from 393 to 251½ at the same temperature (the consumption dropping by about 15 p.ct.). The figures for extra air per c.ft. of gas in the above were 29¾ and 19½ and 29¾ and 22 respectively.

APPENDIX 12.

Effect of Flue Restriction on Temperature Distribution in an Oven.

At a constant gas consumption the effect of restricting the flue outlet is to raise the temperature throughout, and more especially in the lower parts of the oven. It is only when a number of temperature readings are taken at different levels and means are employed to maintain a constant temperature at the top, that the significance of the influence of the restriction in levelling the upper and lower readings is realized. An interesting example may be quoted.

In this case two successive restrictions were made, and a thermostat was used to maintain the top temperature constant. After each alteration, observations were made until two or three thermometers at each of five different levels (as in Appendix 11) were constant when their readings were recorded as follow (corrected to the same A^{w}_{14} reading):

—	Full Flue.	Half Flue.	Net Difference.	Small Flue.	Net Difference.
Level* Aw_{14}	200½	200½	*Nil*	200½	*Nil*
Ax_{13}	194	194½	½	200½	6½
Nx_{13}	197	199½	2½	205½	8½
Ny_{14}	194½	196	1½	203½	9
Ow_{13}	200	201½	1½	210	10
Ox_{13}	194	195½	1½	203½	9½
Oy_{14}	193	193½	½	203½	10½
Px_{14}	187½	189	1½	203	15½
Py_{12}	192	193½	1½	209½	17½
Qw_{14}	169	175	6	199½	30½
Qx_{18}	160	169½	9½	199½	39½

* The readings possible with this drilling of the door are at five levels (A, N to Q) from top to bottom, five holes (v to z) from left to right at each level, and five readings (11 to 15) from back to front at each hole.

The increase at the bottom of the oven, particularly in the last column, is very striking. It must be remarked, however, that any attempt to introduce such an improvement into practice must be governed by the effect on the "Factor of Safety."

APPENDIX 13.

The temperature inside a loaf.

A tin of dough was placed on the fifth grid of oven C2, and a hole drilled through the crown and dome. A thermometer was inserted with its bulb 1 in. from the bottom of the tin. Two other tins were placed on a lower shelf to steady the oven. The test was conducted precisely as described under the C^{b} test instructions. The two bottom loaves were reversed and left on their original grid after 40 minutes, the bake being complete in 50 minutes with this small load—viz., half the usual load of the oven. The loaf under test could not, of course, be moved during the baking. The fig. 10 curves show:

1. The temperature inside the loaf.
2. The temperature at the centre of the oven (C^{b}_{3}), which owing to its position between the three loaves is the lowest of the oven temperatures.
3. The temperature at the top of the oven ½ in. below the dome (A^{b}_{3}).
4. The temperature at the bottom of the oven (E^{b}_{2}).
5. The gas-rate over each period between temperature readings.

It will be seen that the heat penetration to the centre of the loaf is comparatively slow for the first 40 minutes, after which the temperature rises rapidly to about the boiling point of water at which baking was completed.

The last two readings at C^{b}_{3} are low, owing to the removal from, and replacement in, the oven of the thermometer to enable the change to be made. This is reflected in the other readings in the oven, but they only suffered by reason of the door, from which the thermometers were not removed, being opened for a few seconds during the change.

The reading at E^{b}_{2} in the lower part of the oven shows consistently the highest temperature, thus confirming the results shown in the test M 27c (Appendix 11), where two shelves were in use.

The gas rate, after setting for the bake at 16·3 c.ft. per hour, gradually decreases to 15·2 (as already mentioned under Cb test) owing to the gradual heating-up of the supply-pipe and injector-nipples by conduction. Although the effect of this is primarily slightly to increase the nipple-orifices, this is masked by the consequent expansion of the gas; the net effect being a reduction in the volume of gas passed by the nipple.

APPENDIX 14.—*Dimensions of the Various Ovens used during the Committee's Tests.*

Oven.	A, B, C¹, C².	D.	E.	F.	G.	H.	J.
	In.	In.	In.	In.	In.	In.	In.
Side to side	14½	14	22	14¼	13½	15⅜	16⅞
Back to front	13¾	12⅜	19⅜	13⅛	12½	13⅛	15
Teats to dome	21⅜	19½	28¼	21⅛	19⅛	21	22⅜
Between the gates	12⅜	14	20	13⅛	12	14	15¼
Door-sill to 1st runner	3½	⅞	3	1½	2⅛	1½	1½
Teats to door-sill	2⅞	2½	3¼	1⅜	½	1½	1½
Door-opening	21¾ × 13½	17⅛ × 14	25¾ × 20⅜	19¼ × 13⅜	19 × 12	21 × 14	21 × 16
Dome to door frame (upper edge)	−⅜	−¼	−⅜	+⅜	+⅛	−⅛	−¼
Door	22¾ × 14¼	17⅞ × 14½	27 × 21½	19¾ × 13⅞	19½ × 12⅝	21⅜ × 14½	21⅜ × 16½
Door overlap on frame	½	¼	⅜ & ½	½	Sides, ⅜ Top, ⅜ Bottom, ½	½	½
Number of runners	6	5	8	6	5	13	13
Shelves	12⅜ × 11¾	..	20 × 18	12⅜ × 12⅜	..	13⅞ × 11	15¾ × 13½
Grids	12⅜ × 11½	13¾ × 11	20 × 18	..	11¼ × 11¼	13⅜ × 10	15⅞ × 12¾
Slot in dome	6¾ × 1½	11 × ⅜	8¾ × 1¼	8½ × 1	2 half round 2 × 1, and one half round 1⅜ × 1	2 (6 × 1)	2 (6 × ¾)
Flue outlet (effective)	4½ × 1⅜ C² 2 × 1	1¾ round + 2 × ⅛ holes	4½ × 1½	4⅜ × 1*	1⅜ round + 4 × ⅜ holes	4¾ × 1⅜	4¾ × 1⅜
Flue area, sq. in.	5·52 C² 2·78	2·23	5·14	4·66*	2·22	4·66†	4·66†
Teats to drip tin	2¾	3½	2½	2½	3	2	2
Holes per burner	18	14	32	16	15	20	25
Full internal area, above teats, sq.ft.	12·10	9·78	22·31	10·63	9·27	11·51	13·42
,, ,, volume, c.ft.	2·73	2·03	7·06	2·29	1·87	2 57	3·28
Area of "cooking space," sq.ft.	8·95	8·57	17·55	9·00	7·60	9·71	11·64
Volume ,, ,, c.ft.	1·79	1·69	5·00	1·80	1·40	2·02	2·67
Ratio, cooking/full	0·74	0·88	0 79	0·85	0·82	0·84	0·87
Packing	1½‡	None	1½	None	Door only	Door only	..
External casing	A B—Iron C¹ C²—enamel	Iron	Enamel	Triple cased, enamel in and out, tinned sheet centre.	Iron	Iron	Iron
Internal casing	Enamel		Enamel				Enamel

* Not effective owing to a right-angled change of direction of the gases. ‡ A and B have panelled iron exteriors, where the packing is reduced to ¾ in.
† With flue damper.

APPENDIX 15.

The Committee wish to acknowledge their indebtedness to: The Gas Light and Coke Co. for the accommodation placed at their disposal in which to carry out the work; for the loan of much necessary apparatus; and, not least, for the general assistance rendered by their staff in making alterations to existing apparatus, &c., as required from time to time during the progress of the work. To Messrs. John Wright & Co. and Radiation Ltd., for the loan of certain ovens and thermostats at the Committee's request. To Messrs. R. & A. Main, Ltd., for a complete disclosure of their own methods of testing ovens which contained at least one novel feature. To Messrs. Wilsons & Mathiesons for advice regarding baking tests, of which they have had a long experience. To the National Gas Council for the loan of two "Standard" cookers.

APPENDIX 16.

GENERAL TABLES OF RESULTS.

1. MAINTENANCE TESTS.—The reliability of the M test when carried out with the requisite care is strikingly illustrated by reference to the curves shown on figs. 1 to 7. A brief description is necessary for their explanation.

EXPLANATION OF THE CURVES FIGS. 1-7.—N.B. The joints of all ovens are luted with cement, in order to reduce the unknown losses and, by such control of a possible variable factor, to promote a true comparison.

Fig. 1.—*Ovens A and C.* These are internally the same. They differ in that oven A has a cast-iron outer casing with recessed panels which results in less "packing" at the sides than oven C, which has an enamelled wrought-iron outer casing.

Curves 1 *and* 3 show the effect of this difference of construction—*i.e.*, the lower curve (3) for oven C is better by some 46 B.Th.U. per sq.ft. of internal surface per hour. The flue-outlets are full size.

Curves 2 *and* 5 show a similar difference between the same two ovens but with equally reduced flue-outlets. [Curve 2 is located from one observation point and drawn parallel to the nearest full curve.]

Curves 4 *and* 5, oven C, with small flue-outlet show the difference due to leakage of products of combustion from the door No. 4 being unluted at that joint. The door fits very well.

Curves 5 *and* 6.—The difference due to a less thickly packed door in No. 6.

Curve 3, oven C, with full-sized flue-outlet both luted (41 and 43) and unluted (64 and 66) round the door. This coincidence shows that with the large flue-outlet the effect of the gap is indistinguishable.

Fig. 2. *Oven D.*

Curves 7 *and* 8 show the effect of increasing the flue-outlet.

Curves 8 *and* 9.—The effect of unluting the door. The gap is evidently having a greater effect on the M test figure than in curves 4 and 5, and 3 above—*i.e.*, the door is a bad fit.

Curve 8*a* is from another full M test at two temperatures.

Fig. 3. *Oven E.*

Curves 11 *and* 12 show the difference due to door luting—a well-fitting door.

Curve 10.

Fig. 4. *Oven F.*

Curves 13 *and* 15 show the difference due to reducing the flue-outlet. A small difference only, traced to the fact that there was internal friction in the original flue-outlet, which greatly interfered with its effective-

1. Contd. APPENDIX 16.

TABLE I.—*The Order of Merit Discovered by the M Test is given below, both with and without the Door Cracks Luted.*

M Test Nos.	B.Th.U./Sq.Ft./Hour.	—	Order Unluted.
A. Unpacked Ovens:—			
Oven D 40-42	664	Luted	7 and 8
63-65	689	Unluted	
Oven G 48-49	636	Luted	
59-60	690	Unluted	
Oven H 50-51	720	Damper open*	6
	686	Calculated damper closed	
Oven F 44-45	583	Luted	5
67-69	652	Unluted	
B. Packed Ovens:—			
Oven C^1 41-43	559	Luted	4
64-66	559	Unluted	
Oven C^2 37-39	442	Luted	2
60-62	456	Unluted	
Oven J 54-56	504	Damper Open*	3
	463	Calculated damper closed	
Oven E 36-38	415	Luted	1
68-70	430	Unluted	

* These had very well-fitting doors, and although tested unluted and luted, showed no appreciable difference. The difference between C^2 and J is small, as are those between H, G, and D. The packed ovens are appreciably better than the unpacked.

2, 3. TABLE II.—*Heating-up and Smothering Tests.*

Test No.	Rise.	Time.	B.Th.U./Sq. Ft./Hour.	Pressure.*	Test No.	Pressure. Minimum Permissible.	Pressure. Passes At.
A. Unpacked ovens:							
Oven D H57	392-62	10	868	12·7	S18	32	33
G H65	397-57	10	905	13·5	S22	35	35
H H60	392-61	10	1024	22	S24	55	60
F H100	412-62	11	1164	20	S30	50	70
B. Packed ovens:							
C^1 H99	392-59	12	923	16	S21	40	55
C^2 H97	400-66	12	853	13	S19	33	55
J H53	397-60	12	795	9	S25	23	41
E H75	390-55	12	873	16·5	S17	41	68

* Tested as delivered or received from stock, without nipple adjustment. It will be observed that D and G are only just able to pass the S test, while all the others have a good margin.
The effect of the badly fitting door, alluded to under "maintenance test" in section I. above, is shown in the H test No. 100, Oven F.

4. TABLE III.—*Bread-Baking Tests.*

A.—UNPACKED OVENS.

—	Test No.	Heat Units Used for Heating-up. Total B.Th.U.	B.Th.U. /lb.	Heat Units Used for Baking. B.Th U. /Hour.	B.Th U. /Sq. Ft. /Hour.	Time. Minutes.	Initial Temperature °.	Lbs.	REMARKS.
Oven D	Cb1	11,950	1494	8,936	915	69	450	8	Unchanged. Poor bread, front done, back underdone, bottom burned.
	2	12,900	1612	8,880	908	72	430	8	Better than Cb1, changed and reversed. Front and back more equal, less burned.
	3	15,910	1989	8,290	848	80	446	8	Changed twice and reversed. Very good.
	15	11,010	1377	8,431	862	63	412	8	,, once ,, . Very good.
	42	12,060	1092	7,236	740	80	414	11·03	,, twice ,, . Good, but two loaves pale on top and burned on bottom.
	52	12,970	1199	5,773	590	113	414	10·82	,, once ,, . Slightly pale, but no burning.
Oven G	Cb10	12,630	1579	7,778	859	68	428	8	Changed once and reversed. Good.
	16	10,230	1279	7,444	803	66	412	8	,, ,, ,, . Very good, tops slightly pale, bottoms perfect.
	43	10,680	1151	6,428	693	85	410	9·28	,, twice full and thrice minor ones. Ends and tops pale, sides over done. Oven too small to put loaves all in upper half. When shifted, too much headroom to brown.
	45	9,504	1028	6,322	682	76	417	9·25	,, twice full and twice minor. As Cb43, but better bread.
Oven H	Cb4	12,990	1624	11,470	996	50	412	8	Changed once and reversed. One loaf badly burned bottom and sides.
	12	13,990	1737	10,320	897	50	428	8	,, ,, ,, . Unequal browning traced to unequal burners.
	19	10,870	1359	10,600	921	48	412	8	,, ,, ,, . Excellent bread; damper closed here and afterwards.
	28	16,310	1165	11,040	959	76	412	14	,, twice ,, and several minor. Tops pale.
	33	13,510	1126	9,383	815	74	412	12	,, once ,, ,, ,, . Patchy, with tendency to burn rather than brown.
	35	13,510	1126	9,137	794	76	414	12	,, twice ,, . Very good.
	38	14,230	1026	9,105	791	80	408	13·875	,, ,, ,, . Pale owing to being low in new large tins
	40	15,050	1066	9,031	784	84	415	14·125	,, ,, ,, . Like Cb38, and for same reason.
	48	14,810	1083	7,307	635	112	417	13·667	,, ,, ,, . Pale on top, similar to Cb45, but much better.
	50	13,990	1040	7,506	652	100	412	13·448	,, ,, ,, . A trifle pale, but better than Cb48.
Oven F	Cb6	11,680	1460	9,585	902	52	408	8	Changed once and reversed. Outer sides burned at bottom.
	14	10,840	1355	9,335	878	44	412	8	,, ,, ,, . Excellent.
	29	13,300	1109	9,056	855	60	410	12	,, twice ,, . Tops on one or two slightly pale, good.
	41	13,660	1139	7,775	731	82	408	12	,, ,, ,, . Good, starters on bottom shelf paler than others.
	44	13,350	1112	8,258	777	75	414	12	,, ,, ,, . As Cb42.
	47	14,530	1211	6,637	624	109	412	12	,, ,, ,, and one minor. Equally done, but slightly pale.
	49	13,370	1063	6,878	647	95	432	12·56	,, ,, Very good,
	51	14,350	1196	6,455	610	104	418	12·3	,, ,, ,, Pale.

B.—PACKED OVENS.

Oven C¹	Cb8	11,290	1411	9,583	792	50	428	8	Changed once and reversed. Best batch baked.
	17	10,490	1311	9,627	796	48	412	8	,, ,, ,, . Very good, slight paleness at tops.
	21	12,880	1073	9,369	774	60	410	12	Top and bottom changed, once middle reversed. Good.
	39	13,070	1089	7,665	633	75	410	12	Changed twice and reversed. Good.
	46	12,490	1041	7,857	649	74	410	12	,, ,, ,, . Excellent.
Oven C²	Cb7	11,690	1461	12,340	1020	59	403	8	Changed once and reversed. As Cb6 outer sides, burned at bottom.
	13	10,530	1316	9,508	786	50	424	8	,, ,, ,, . Very good,
	22	11,840	987	9,279	767	60	414	12	Top and bottom once, middle reversed. Better than Cb21, but tendency to burn.
	24	11,820	985	9,219	762	60	415	12	,, ,, ,, ,, ,, . Bread fair to good, but spoiled by the studs in the dome of the oven.
	26	11,190	932	9,396	776	57	412	12	Changed twice and reversed, and several minor. Tendency to burn before browning.
	37	11,210	935	7,563	625	70	412	12	,, ,, ,, . Good bread, but slight signs of burning on one edge; initial period before first change too long.
Oven J	Cb5	13,280	1680	10,470	780	50	435	8	Changed once and reversed. Good bread.
	18	10,130	1266	9,397	670	42	412	8	,, ,, ,, . Excellent (damper closed here and after).
	23	16,030	890	9,391	700	80	410	18	,, many times. Under browned and badly burned.
	25	17,890	994	9,406	705	87	410	18	,, ,, ,, . Better than Cb23, but unsatisfactory.
	27	16,890	938	9,309	694	87	408	18	,, ,, ,, . Fairly good, but pale on top. [Cb23, 25 were all long low loaves and thus difficult to brown.]
	32	14,690	918	9,076	676	72	421	16	,, twice and reversed. Patchy, tendency to burn rather than brown.
	34	14,220	889	8,431	628	77	415	16	,, ,, ,, . Very good.
Oven E	Cb9	21,100	1319	18,220	816	50	437	16	Not changed. Overdone all over and parts burned.
	11	18,780	1174	18,030	808	44	423	16	,, ,, . Excellent, but slight traces of burning.
	20	20,410	850	17,940	804	49	415	24	,, ,, , but after removal of top tier, bottom tier put on top for 3 minutes. Very good.
	30	25,390	846	17,670	792	65	410	30	Changed many times. Good, but several pale tops.
	31	28,310	786	17,460	782	78	414	36	,, ,, ,, . Very good, one of the best lots baked.
	36	27,300	758	14,850	665	90	412	36	,, twice and reversed. Very good.

ness; the smaller flue-outlet thus reduced the effective area by a very small amount.

Curves 13 *and* 14 show the difference between luted and unluted door cracks; this door is evidently a bad fit.

Fig. 5. *Oven G.*

Curves 16 *and* 17 show door cracks luted and unluted.

Fig. 6. *Oven H.*

Curves 18 *and* 19 show damper in the flue-outlet open and closed.

Fig. 7. *Oven J.*

Curves 20 *and* 21 show damper open and closed.

N.B.—Curves 8, 19, and 21, like curve 2, are located

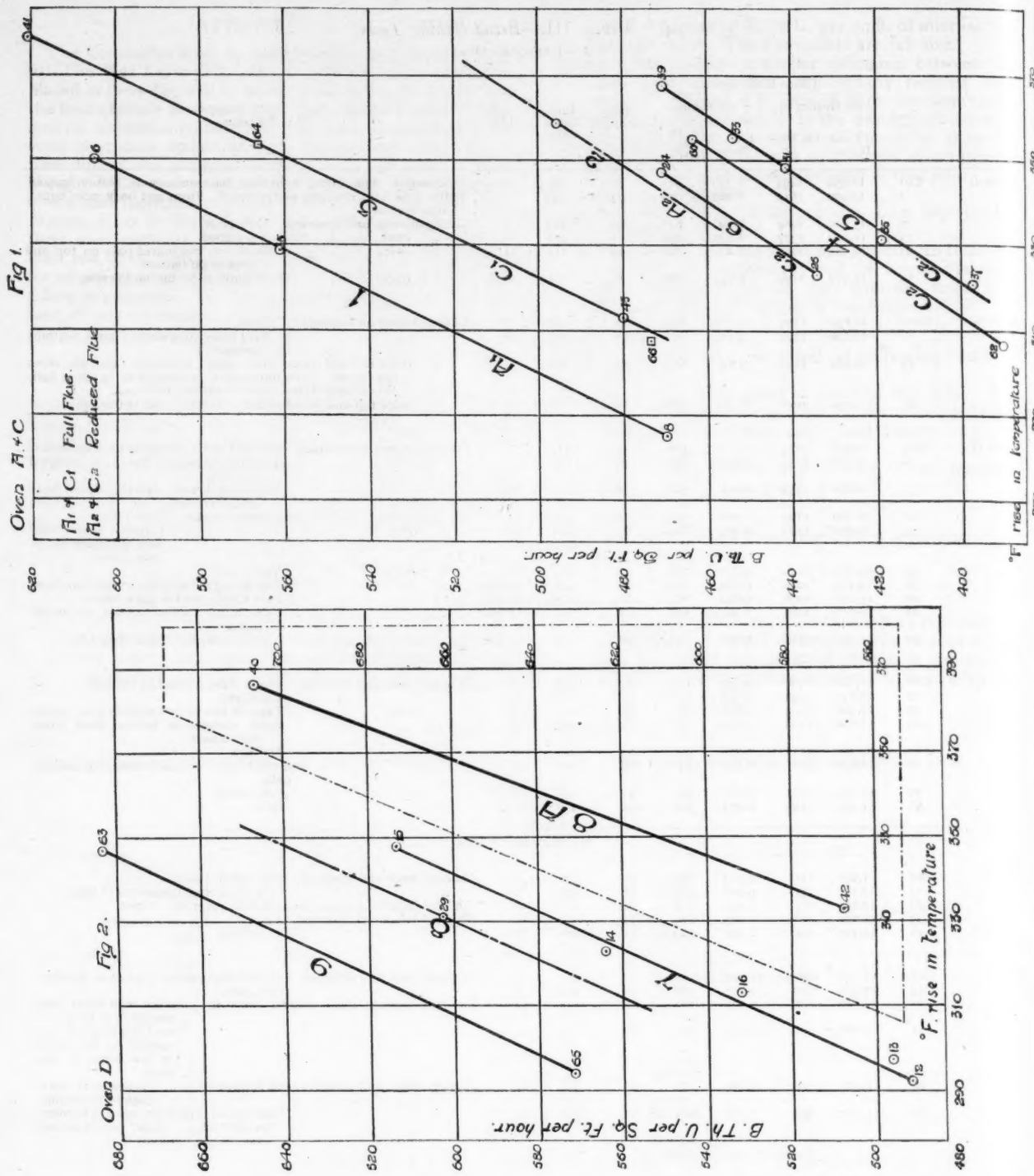


Fig 1.
Oven A + C
A1 + C1 Full Flue.
A2 + C2 Reduced Flue
B. Th. U. per Sq. Ft. per hour
°F. rise in temperature
Fig 2.
Oven D
B. Th. U. per Sq. Ft. per hour
°F. rise in temperature

from a single point and drawn parallel to the nearest full curve, and are shown broken in figs. 2, 6, 7, and 1 respectively.

That the effect of such small alterations should be so unmistakably shown by the curves is considered by the Committee to show the reliability of the test put forward.

Examination of the results will show what a difficult task the Committee have had in attempting to lay down a method of procedure.

As the load is increased, so is the tendency to burn, necessitating a reduction in the gas and a lengthening of the time. With this reduction appears a difficulty in getting the upper parts of the loaves to brown. This difficulty does not occur in ordinary bakeries, as the loaves are mainly baked by radiation from the roof and conduction from the floor, through the tins. In the large oven E more than two loaves are side by side and, if due attention is not given to the shifting from their places of the centre ones at the change, they will be less done than the outer ones. Long low loaves do not brown easily on a shelf designed to take an ordinary loaf, thus indicating that contact with the hot gases is a necessity in a gas oven of the type under test.

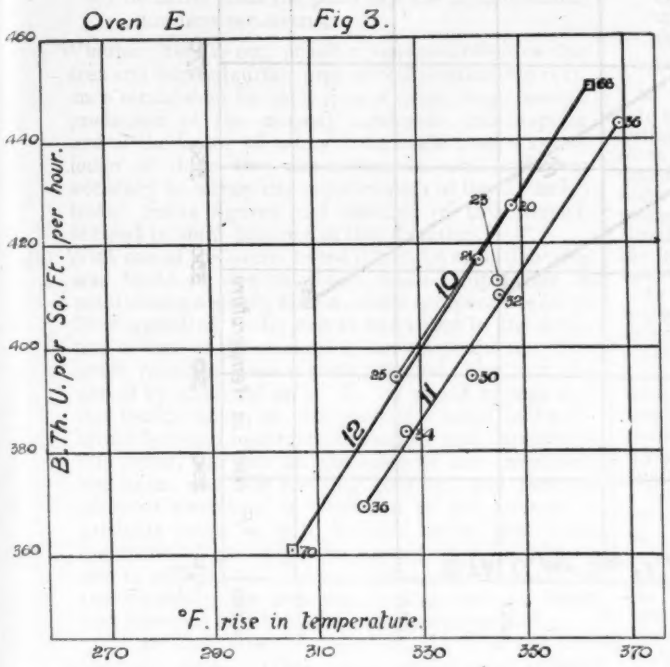
Taking one thing with another, the order of merit appears to follow very closely that of the one discovered in the M tests. In spite of possibly good B.Th.U./lb. figures, small ovens are not so satisfactory at full load as are large ovens, owing probably to the greater space that begins to show between the walls and the tins in the latter. The former need usually more attention, and do not so easily give equally browned loaves. All these points will be discovered in a Cb test, and will be considered by the responsible official, but they cannot be put into tabular form, and their merits and demerits exactly assessed.

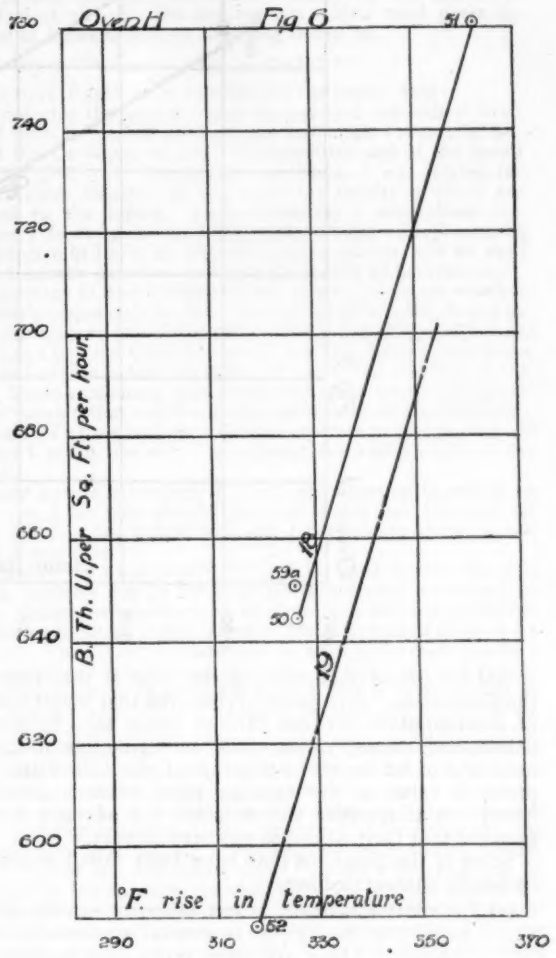
APPENDIX 17.

Temperature Gradient in an Ordinary Oven with one Browning Shelf.

Fig. 8a shows the temperature, in an oven constant at about 180° C. (or 360° F.), taken at intervals of one inch from the left side wall towards the centre and equidistant from the back and door and from the dome and burners.

Fig. 8b shows similar readings taken from top to bottom

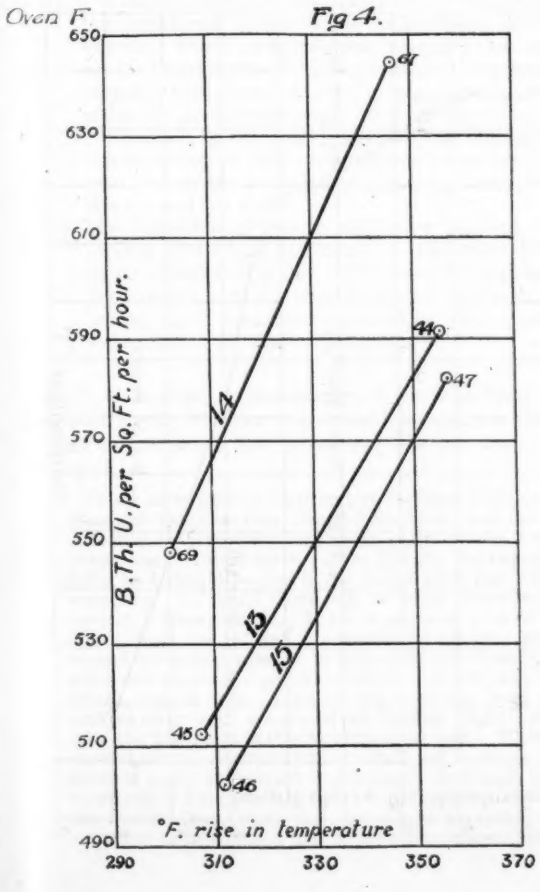


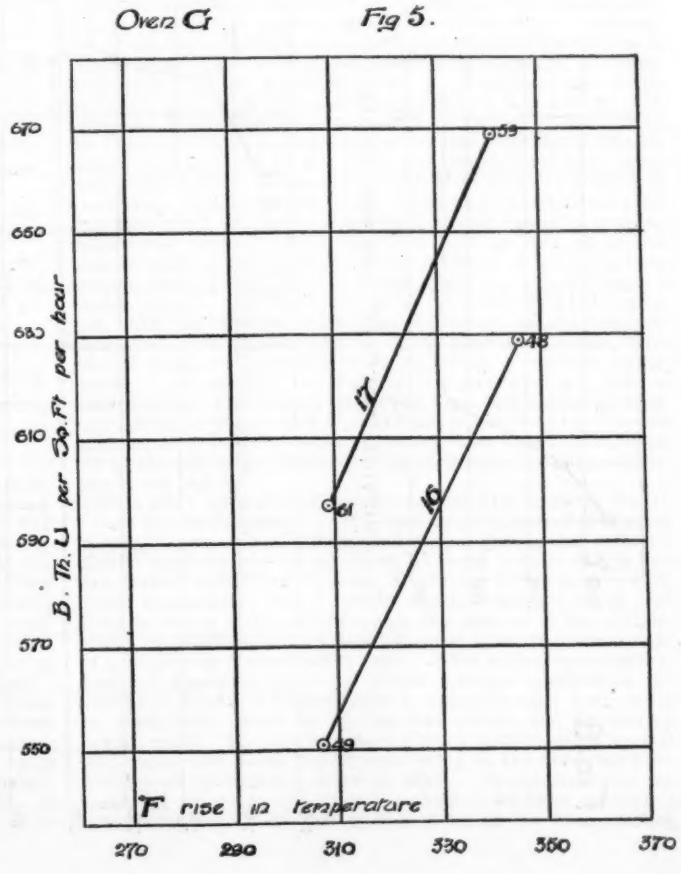


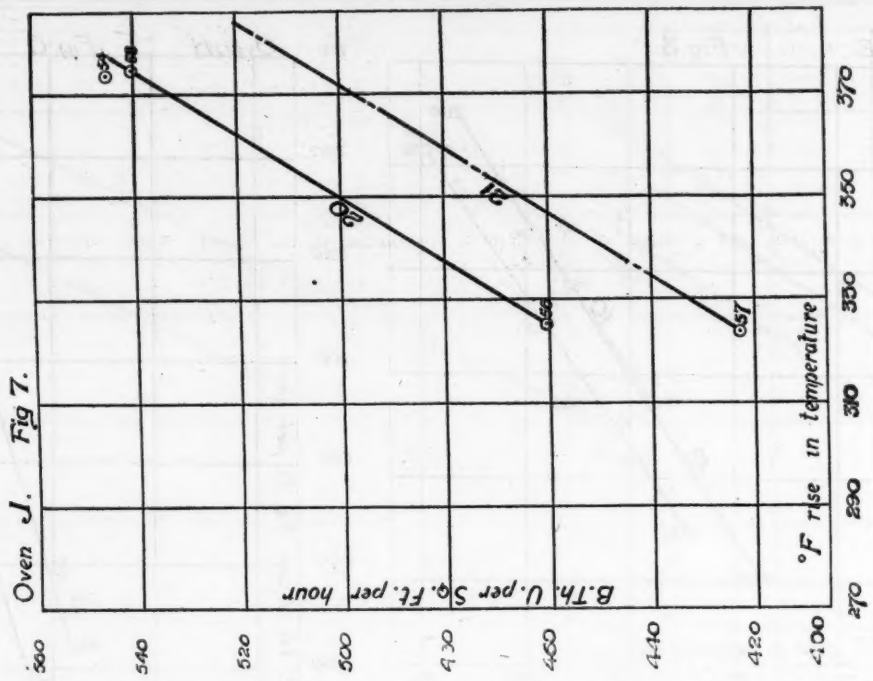
of the oven. The drop above the browning-shelf and below the first runner or grid support is noticeable.

APPENDIX 18.

The Committee in putting forward the schedule of tests in this Report would not suggest that they are the last word on the subject, or that they represent finality. In an investigation of this sort the results obtained during the experimental work inevitably bring up further points which seem worthy of consideration and following up. At the same time a limit has to be set to the lines of investigation so followed, or the presentation of a report would have to be indefinitely postponed. These remarks apply with particular force to the bread-baking test. That part of the work had so many apparent lines of attack that to develop them all







would have been impossible in the time at the disposal of the Committee. It is, however, believed that sound methods of differentiation between various ovens have been established, and should these, while satisfying the immediate need which led to the setting-up of the Committee, also prove of value as the starting point towards something better, the Committee will welcome the advance and feel gratified that their work has not been in vain.

Some of the questions that have been raised might well be briefly enumerated here.

(1) No effort was made to test other than ovens of ordinary types such as are in general use throughout the country. There are other types such as externally heated ovens, and their various modifications; there are also the representatives of more modern design and construction, all of which merit attention.

(2) There is the question of the temperature requisite to cook various foodstuffs—*i.e.*, what internal temperature must be attained in such foodstuffs and what is the mechanism of the cooking. Does some food require internal temperatures above 212° F. (the boiling point of water)?

(3) Allied to No. 2, but capable of separate treatment, is the possibility of substituting a test, such as the time and gas required to attain a given temperature gradient in a mass of (say) sand, for the M or Cb tests, or both.

(4) Whether in the Cb test closed tins might not

(*a*) be more convenient, as the bread cannot expand beyond the confines of the tin and touch the bottom of the next higher shelf.

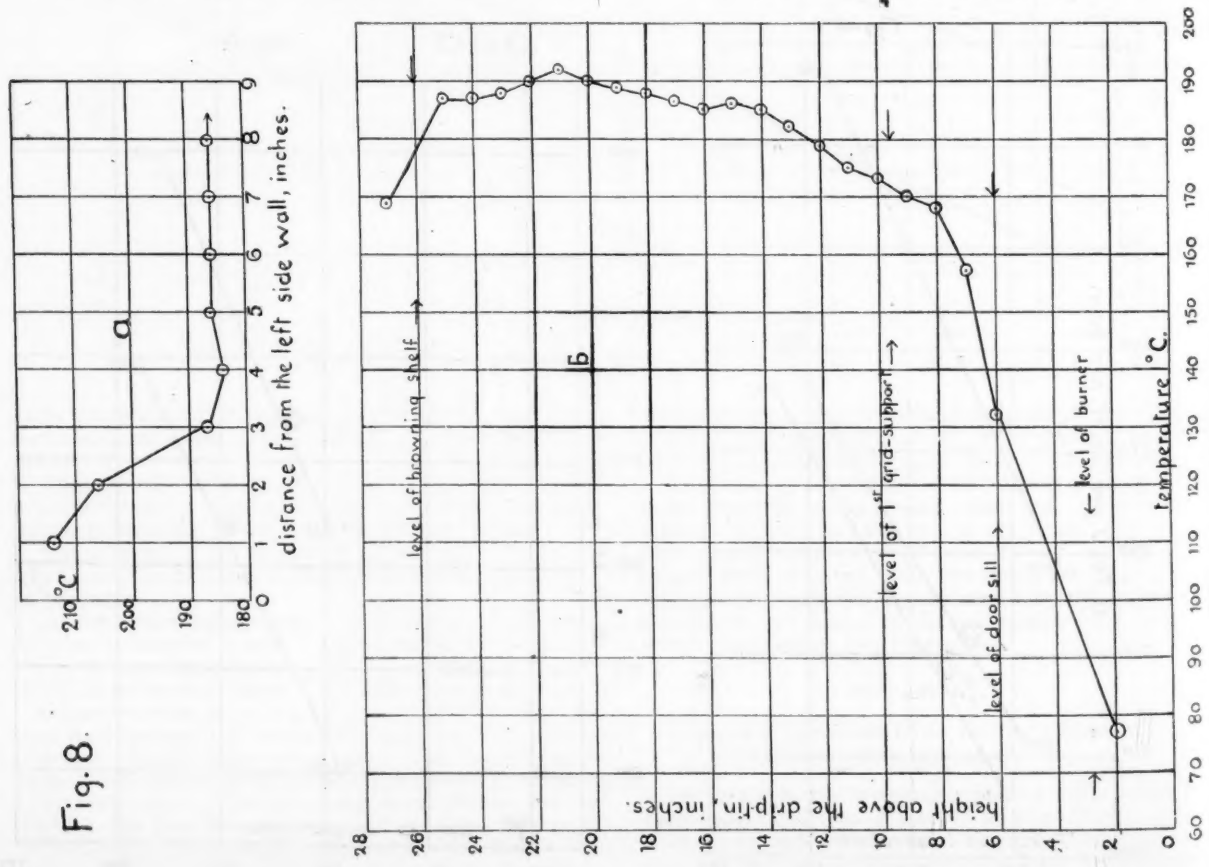


Fig. 8.

(*b*) be better from the point of view of differentiation between ovens.

(5) Whether there is not, possibly, between effective flue area and internal surface area, a fixed relationship that, once established for each type of oven, might enable prediction of the normal maximum consumption and/or the factor of safety to be made from a knowledge of these two measurements with sufficient accuracy to satisfy the requirements of the H and S tests. Some figures, not detailed in this Report, seemed to show promise in this direction.

(6) With one of the ovens tested (Oven D) some difficulty was found at one particular mean temperature in maintaining a steady bottom check temperature (E^b_2). This appeared to be due to variations in the direction of flow of the streams of heated products. The other readings were hardly affected, but this one varied by some 20° or 30° C. It would appear that this thermometer, at this particular state of equilibrium between upthrust of products and capacity of flue outlet, was just on the edge of the circulating hot gases and the entering cold air, and that the slightest alteration in direction of the streams of products (such as with burners set to pass equal quantities of gas might be caused by a disturbance due to walking past the oven) was sufficient to bring the boundary line between products and air either just above or just below the thermometer bulb.

As an illustration of the effect, the following consecutive readings taken over a period of 40 minutes may be quoted :—

A^b_2 . . .	213	211	211½	209½	208
E^b_2 . . .	219	188	188	215	186

Readings taken at level D, which is a few inches above level E, showed that the variation extended that far; but it was not so great, and was there confined to the centre readings at b, the side readings at a and c being hardly affected, *e.g.*

D^a . . .	202	205	202	202	200½
D^c . . .	206	200	200	203	202
D^b . . .	200	210	197	207	198
E^b . . .	200	220	186	215	186

A thorough exploration of the lower levels with more observation points for thermometers might yield precise information as to the shape of the boundary between hot products and cooler entering air.

(7) The effect of steam in the oven with which is bound up the question of saturation of the products with water vapour. The Committee was informed that steam is used in bakeries as a browning medium. In special cases steam is introduced into the atmosphere of the oven either by providing vessels of water near the fire, or from jets. It has been suggested that in closed tins the browning of the loaves is greatly due, not to direct heat, but to the envelope of steam retained between the tin and the loaf.

(8) The influence of quick and slow cooking on the quality of the food produced. A suggestion has been made elsewhere on this with reference to bread. At least one loaf of all batches baked was retained for eating, and favourable comments were passed on bread baked for the longer periods.

Mr. C. F. BOTLEY: In the absence of Mr. Broadberry, I have, before asking Mr. Forshaw to give you a summary of the report, to read a letter which Mr. Broadberry has sent him. It is as follows:

"I am sorry that as Chairman of the Special Committee on Standard Tests for Gas Ovens I shall not be at the meeting to testify, in presenting the report, to the excellent work you have done. I must leave you to present the report; but in doing so I should be glad if you would read this note to the members. No doubt there will be great discussion of the subject, if time permits. There is certainly a lot of material and ground for it; and I strongly advise that your reply should be communicated in writing to the Technical Press after you have seen and weighed-up very carefully anything which may be said. A lot of the work has been difficult; and we have been convinced all through that it constitutes only the first steps in this important subject. We have been careful not to specify anything which will bind the manufacturer in a way to prevent improvement in design, but rather to establish a standard to which they can work and by which the results they obtain may be valued by comparison. It must not be overlooked that in trying to achieve good results in the first three tests there still remains the last and most critical of all—viz., the cooking test, which must never be omitted, because it is the crowning test of all."

I formally move the adoption of the report.

Mr. ARTHUR FORSHAW, in introducing the report, said:

In introducing the special report on standard methods of oven testing I wish, in the first place, to say how much I regret the absence of the Chairman of the Sub-Committee and of the Small Committee (Mr. A. E. Broadberry), on whom I was relying for some prefatory remarks on the work, the results of which are embodied in the report. Since, however, I understand Mr. Broadberry is away on the honourable mission of representing the Institution in Paris, his absence is unavoidable; and we shall have to reconcile ourselves to losing the benefit of his remarks.

As Secretary of, and Chemist to, the Small Committee which is immediately responsible for the report, I should also like to put on record my appreciation of the efforts of Mr. Broadberry, Mr. J. G. Clark (Gas Light and Coke Company), and Dr. Hartley (Radiation Ltd.), and of the other members, to assist the success of the work. These gentlemen have invariably made themselves available for consultation and discussion, often at considerable inconvenience. We have had some difficult matters to decide; and for my part I could not wish for a better team with which to co-operate.

Coming now to the report, it is not my intention to read it *in extenso*, nor I am sure would it be your desire that I should do so. It lies in print before you, and I propose to deal with the salient points only.

In considering a test or series of tests for apparatus of this sort, the first business was to decide on the information we wished to obtain. After due consideration we drew up a series of questions, the answers to which would afford all the information likely to be required. The schedule of tests put forward in the report enables answers to these questions to be made. We also put before ourselves certain ideals to which the form of test or tests should as far as possible approximate. These questions and ideals will be found in Appendix No. 8.

Of the questions there set forth, the first in point of consideration, though not necessarily the first in importance, is No. 6,—viz.: "Does the oven heat-up in a reasonable time?" As an instance of the type of difficulty against which we have been continually finding ourselves during the course of investigation, this question may be cited, for it immediately leads to the further query: "What is a reasonable time?" Such a query cannot be answered by any appeal to chemistry, physics, or mathematics, but only by common sense, which in such cases means the greatest common measure of agreement between the possibly divergent views of the members of the Committee. However, our individual experience and a knowledge of various printed instructions led us to the conclusion that the generally accepted reasonable time is ten to fifteen minutes.

Then arises another question, What does the rather loose expression "heat-up" mean in precise terms? Obviously this question may only be answered by a knowledge of the temperature required for various cooking operations. With regard to these, it is of course well known that there is a considerable difference between the optimum temperatures for cooking a rice pudding, for instance, and for a joint of pork. As all ordinary and likely foodstuffs have to be taken into consideration, it is evident that some sort of compromise will have to be arrived at in defining the "heat-up" temperature, while at the same time the maximum temperature required for any particular foodstuff will have to be readily attainable. We were thus led to the idea of the normal maximum consumption, which we define as that maximum consumption which may be required for the initial stages of cooking operations. Such a consumption will heat an oven up to the highest temperature required by any foodstuff if left for a long enough time. It will heat a packed oven up to 400° Fahr. in twelve minutes; and this fact we make the basis of the heating-up test. We vary the time to ten minutes for an unpacked oven, because the latter usually heats-up rather more easily owing to its smaller mass, and because when heated up it requires rather more gas to maintain the required temperature than does a packed oven. The heating-up test is, then, that a packed oven must obtain a temperature of 400° Fahr. in not more than twelve minutes, an unpacked oven in not more than ten minutes, when set at the minimum pressure of the district, or 20-10ths, whichever is the higher.

With this matter of heating-up is connected the question No. 1: "Does the oven smother?" If it were not for the need of making certain that an oven is quite safe, however greatly the ordinary district pressure may be increased at some periods during the day, there would be no objection to an oven having such a high initial consumption that it would attain a temperature of 400° Fahr. in two or three minutes (apart, of course, from the undesirability of providing such a possible cause of waste in the hands of a careless or inexperienced user). With such a consumption, however, a possible rise in the district pressure might cause the volume of products of combustion to become greater than could be dealt with effectively by the flue outlet; and smothering would result. To answer question No. 1 and to guard against any reasonable possibility of smothering in the oven, we have introduced the idea of a factor of safety. To ascertain that the factor of safety of any oven is sufficient, we have specified a smothering test. This test is carried out on the oven, starting

from cold, at a pressure 2½ times that necessary to provide the normal maximum consumption. This pressure will give an increase of approximately 60 p.ct. in the gas consumption over and above the normal maximum consumption. Our experience and our inquiries lead us to consider this to be a reasonable factor of safety.

Passing on to question 4: "Is the oven economical in gas consumption?" We have provided the answer to this, in a physical sense, by means of a maintenance test. The basis of this test is the determination of the heat units required to maintain within the oven a constant temperature above that of the surrounding air. The expenditure of these heat units is necessary to make up for the heat which passes through the walls of the oven and is lost in the form of convection and radiation, and for that which escapes in the products of combustion through the flue outlet. For purposes of comparison between one oven and another, the total number of heat units required is divided by the internal superficial area of the oven above the level of the teats; and in this way a figure for heat units used per square foot of area is obtained.

As the stabilization of an exact temperature within the oven of 350° Fahr. above that of the room is a matter of some tediousness, we have adopted the device of taking two consecutive tests; one with a slightly low and the other with a similarly high rise referred to the exact rise at which the comparison between ovens is to be made. By plotting the two results on squared paper—viz., rise maintained against heat units per sq. ft. used—the number of heat units used for the exact rise of 350° Fahr. is determined by interpolation on the curve.

The determination of the temperature within the oven is made by means of thermometer readings at 27 different points. We tried a large number of arrangements of thermometers before deciding on that specified in the report. The greatest number tried was 125 readings; and the records so obtained are, we think, the most complete ever attempted in a cooker oven. We also tried fewer than 27; but we came to the conclusion that this number was the least permissible consistent with accuracy. The exceedingly close way in which the results of repeated maintenance tests agree is the best guarantee of its suitability for the purpose. The results of numerous tests are shown in figs. 1 to 7, and the influences of very small alterations to ovens are unmistakably shown in a remarkable manner. In fact, so good are the results, that on one occasion, one of them failing to come into line, I immediately suspected its accuracy, and was enabled to find an error in the arithmetical working-out, which when put right brought the result into its expected place on the curve.

Returning to the questions in Appendix 8, the others depend for their answers mainly on the bread-baking test we have put forward. We have based this test on the space provided by the maker for cooking purposes—viz., that bounded by the lowest grid support, the dome (or internal top), the gates or hangers on each side, and the back and front of the oven. As this is space presumably provided for cooking purposes, in our test it is measured, and then loaded with dough in proportion to its capacity. In the actual baking test the oven is first heated-up to a definite temperature at the normal maximum consumption already determined by our heating-up test. When this temperature (410° Fahr.) is reached, the dough is placed in the oven in open tins, and the consumption altered to a definite one based on the gas necessary to maintain a definite temperature in the oven, as already found by our maintenance test. By adopting such a procedure the conditions are made as comparable as possible for each different oven. The object of the test is to produce evenly-browned bread.

Our experience, on which the test is based, is that ovens show considerable differences in this respect. Owing to their design, some ovens will tend to cause the bread to burn at the bottom before they cause browning on the top; and by our specification of the exact loading we endeavour to accentuate this tendency as a means of differentiation between various ovens. In order that the tendency may not become so pronounced as to affect all ovens, and so interfere with the desired result, we allow, if necessary, during the baking not more than one or two strictly defined changes of position of the loaves according to the number of tiers in the oven. By this relaxation we enable a loaf, the bottom outside edge of which would inevitably be burned through continued contact with the hottest portion of the products of combustion, to be moved so that this part goes to a cooler place in the oven, while at the same time, as browning on the top of the loaves proceeds mainly at the top of the oven, each loaf in turn occupies a place where browning may proceed.

It might be argued that if we had reduced our initial loading such changes as described would be unnecessary. To a certain extent this is true; but we also found that with our full scheme of loading we got a further differentiation between ovens, not only in respect of equality of product, but also in respect of gas used per lb. of bread baked. We found again that the greater the load, so long as it is not too great, when burning before browning always takes place, the better the figure for gas used per lb. of bread.

If the test under the conditions specified does not succeed in differentiating between the ovens, further tests are made at altered gas rates; but throughout (for reasons discussed in the report) we used the specified load of dough. When all necessary tests have been made, a number of factors are to hand on which to base a decision as to the order of merit of the ovens used. For instance, time, gas used, ease with which equality of baking is obtained, number of changes required, and so forth have all to be taken into consideration by the official responsible for the decision. It is of course well nigh impossible to give some of these factors comparative numerical values; it is, moreover, conceivable that some of them are of greater value in one neighbourhood than another. As an instance of this, with cheap gas the figure for gas per lb. may not be so significant as the possible saving in time, whereas with gas of high price this figure may be worth saving on at the expense of longer time.

With regard to question 5, "What percentage of the total space of the oven is available for cooking?" I should like to make one or two remarks.

The first is that the cooking space is not an invariable space in any one oven. It depends on the class of food being cooked. The more gas one has to use, the greater side-space is required by the products of combustion to rise to the top, otherwise the food in immediate proximity to the stream of products will be burned. The more space there is left at the sides, the less probability there is of this happening. At the same time, the more space thus left, the greater the gas used per lb. of food cooked. The actual cooking space is then something in the nature of a compromise in any particular oven.

The second remark is that, so far as our measurements go, the proportion of total space above the teats, which is fitted by the maker to take food or utensils, varies considerably not only from maker to maker, but also in the ovens from any one maker. The result of this variation will appear more or less in our bread baking test. Where the cooking space provided is on the small side, the test will show bread more easily browned without burning, but it will also cause the gas per lb. to go up. Where the maker, on the other hand, has provided a large cooking space, there will be more difficulty in getting the bread browned without burning, but provided the bread can be properly baked, a low figure for gas per lb. will be obtained. I should expect in some cases that it would be almost impossible to bake the bread equally to a brown colour with the load based on the cooking space. If such a case did occur, the optimism of the maker (shall we say) would prove unjustified; for, to get reasonable results, the load, and therefore the potential cooking space, would have to be reduced.

I think I have now traversed the ground covered by the schedule of tests. I do not propose to touch on the matter included in the Appendices, as these are self-explanatory. Before finishing my remarks, I should, however, like to emphasize that as a Committee we have had a difficult task, particularly with regard to the practical baking tests. As the individual responsible for the experimental work, I should like to say that had we taken a further year to elaborate our practical test it would have been time well spent. There are so many directions in which investigation should be pushed forward, that for a man single-handed (as I was) such time would have been none too long for the purpose.

As a Committee, we realize that the work, good as we make bold to think it, is by far from being the last or best possible word on the subject; and we trust that the inherent difficulties will be borne in mind in the discussion which we hope will ensue. An attempt at standardizing oven tests has long been overdue, and the results of the first one, appropriately organized by this Institution, now lie before you.

Mr. PATERSON: I have pleasure in seconding the adoption of the report.

The PRESIDENT: I take it that the late hour is responsible for a certain reluctance of members to rise to discuss this report. In the circumstances, any criticisms of the report would better be made in written form, when they will be welcome and receive the serious consideration of the Committee. Therefore, I will put the motion which has been proposed and seconded.

The report was adopted.

REFRACTORY MATERIALS.

Owing to the considerable length of the Reports and Papers presented at the Institution Meeting, we have decided to publish the communication by Mr. W. Emery on "Silica Gas Retorts" and the Report of the Refractory Materials Joint Committee, with the discussion, as a Supplement to next week's "Journal."

THE REGENERATIVE COAL GASIFICATION SYSTEM AT AYLESBURY.

By A. G. LANE, of Aylesbury.

About two years ago, owing to the extension of area of distribution and increase of business, it became necessary to increase the capacity of the carbonizing plant at Aylesbury, and while this was under consideration, Messrs. Travers and Clark introduced their Regenerative Coal Gasification System. A proposal was laid before the directors of the company and was referred by them to the Chairman, Mr. G. Ball, upon whose recommendation a contract was entered into for the construction of a complete gasification plant rated at 300,000 c.ft. per 24 hours. The plant was constructed and set to work in February, 1923.

In this process of complete gasification the coal is transformed into gas in a single operation, leaving only ash, liquor, and tar as residuals, and in such a manner as to render a very large proportion of the energy of the coal available and saleable as town's gas. The carbonization of the coal is effected by internal heating, that is to say by the direct transference of the sensible heat to the coal of gas passed through it, at a high enough temperature, and in sufficient quantity, to complete the process. The heat used is recovered regeneratively from the blow or waste gases, hence the title Regenerative Coal Gasification System. External heating of the coal does not enter into the process, in which retorts are not used.

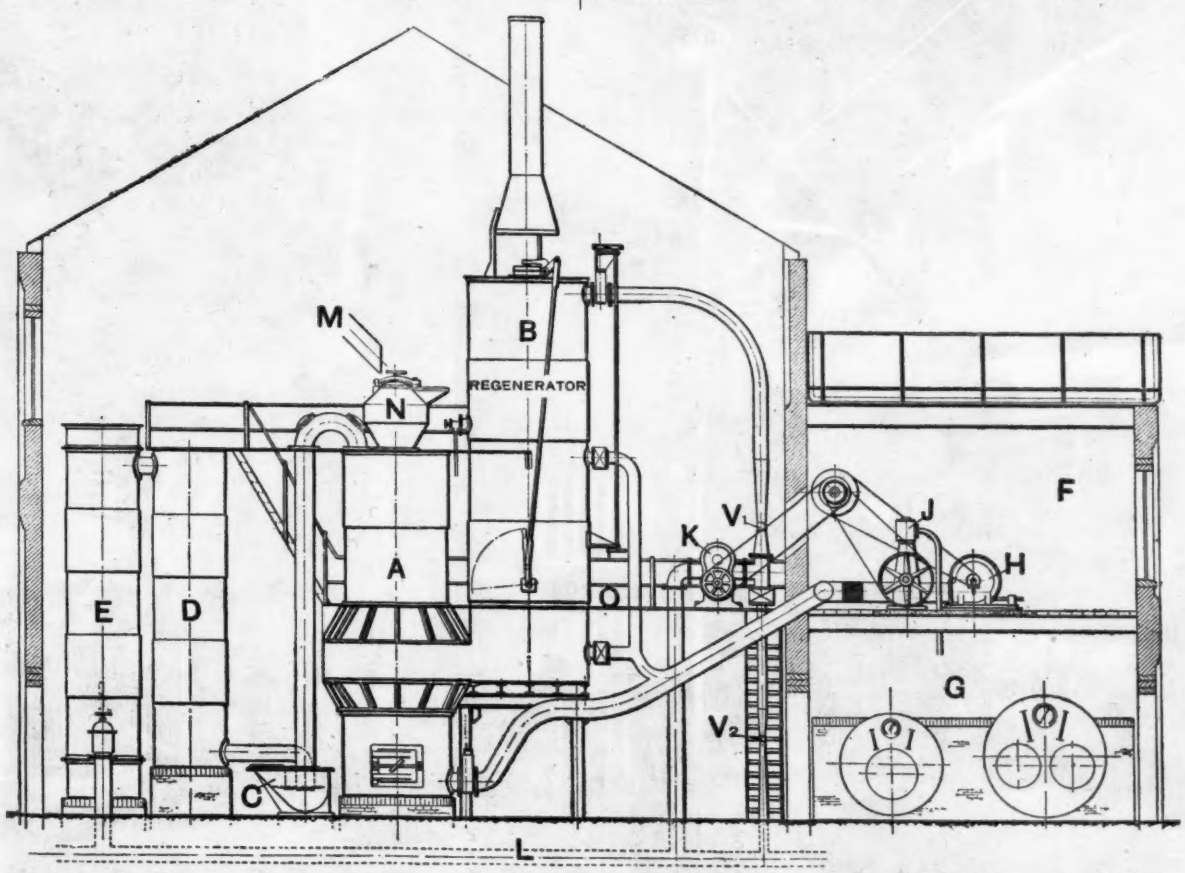
Fig. 1 shows the general arrangement of the complete gasification machine, and the building in which it is located. A carburetted water gas-plant, erected in 1900, formerly occupied the site of the new plant and produced about one third of the quantity of gas which is now made by this new system. Existing boiler, blower, engine, scrubber, and condenser were utilized; consequently the plant is somewhat cramped.

The generator A consists of a steel shell lined with firebrick, insulated with slag wool. The lower portion is somewhat similar to a water-gas generator, having air and steam inlets, with the usual valves, and an off-take pipe for the down-run gas, all arranged below the firegrate level.

The lower part of the generator is known as the gasification section, as in it the coke produced by the carbonization of coal in the upper part, or carbonization section, is converted into water gas and blow gas by the alternate action of steam and air. The carbonization section or chamber is continuous with the lower part of the gas producer, and is furnished with a coal hopper N, a coal feeding device, and a gas off-take pipe leading through a wash box (of special design), scrubber D, condenser E, and outlet main to the relief holder. At a level in the gas producer, intermediate between the regions of carbonization and gasification, a circular channel is formed which communicates with the regenerator B. Through this channel the blow gas passes from the top of the gasification section of the plant into the regenerator, without passing through the coal in the carbonization section, and through it the heated circulation gas passes from the regenerator to mix with the water gas passing from the gasification to the carbonization section of the plant during the run. The circulation gas is drawn from the outlet main, and forced by the circulator into the regenerator; the gas first passing through an orifice meter, whereby the quantity of gas being circulated can be determined, and read off on a gauge indicating cubic feet of gas per minute.

The routine of normal working is as follows. During the blow, air enters under the gas producer grate, and the blow gas passes through the regenerator, escaping from it through an ordinary stack valve. Secondary air is admitted to the regenerator as necessary.

At the end of the blow the air-valve is closed, steam is admitted to the bottom of the regenerator, and, after allow-



A—Gas Producer. B—Regenerator. C—Wash Box. D—Scrubber. E—Condenser. F—Engine Room. G—Boiler House. H—Blower. J—Steam Engine. K—Circulating Machine. L—Outlet to Relief Holder. M—Coal Shoot (from Overhead Hoppers). N—Coal Charging Hopper. V_1—Venturi Gas Meter, No. 1. V_2—Venturi Gas Meter, No. 2. O—Operating Floor.

Fig. 1.—General Arrangement of the Complete Gasification Machine.

ing a few seconds for scavenging the plant, the stack valve is closed. By means of a special mechanism the valves controlling the admission of circulation gas to the regenerator, steam to the circulator engine, and also to the turbo-blower are operated simultaneously, the speed of the circulating engine being increased and that of the blower slowed down. The rate of circulation is controlled by a valve at the inlet to the regenerator, the volume of gas circulated being read off directly on the gauge which has been referred to.

During the up run, which occupies the first part of each run, gas is circulated through the machine. After stopping the circulation and before commencing the down run, steam is passed through the regenerator, so as to drive the gas left in it forward into the generator, and through the carbonization chamber. The down run valve is then opened ; during the down run steam is preheated in the regenerator, and at the end of the run period the regenerator contains steam only.

Rich gas, mixed with a large quantity of steam, is given off from the coal in the upper part of the plant during the blow period. A method has been devised by Messrs. Travers and Clark, which they have patented, whereby this mixture of gas and steam is passed into the condenser, and the permanent gas is drawn off through the circulator and delivered to the relief holder.

The circulator K on which so much of the mechanical efficiency of the process depends, is manufactured by the Sturtevant Engineering Company, Ltd., and is capable of handling the required quantity of gas against a high resistance. Although the duties of this circulator are by no means light, the machine has from the start behaved in a most satisfactory manner, and never caused the slightest trouble.

The operation of the plant, including the charging of the generator with coal, is carried out by one man, without assistance. Clinkering is carried out by two men in about ten minutes.

The plant at Aylesbury has been in operation for the past fifteen months. As the Gas Company is under contract to supply coke to certain customers, but particularly as the blower and circulator are not in duplicate, it is considered advisable to maintain a section of the retort bench in operation, thus ensuring continuity of the gas supply in the event of accidental breakage of any of the machinery. The writer is pleased to say no accident has happened.

As the capacity of the whole plant is much in excess of the demand, it has, however, only been possible to work the new plant intermittently, and for between four and eight hours a day. In spite of this the plant has worked in a most satisfactory manner, and even after standing over for 18 hours, after clinkering the fire it is only necessary to lengthen the first few blowing periods before proceeding with the regular plant routine.

The longer the stand over, the greater the quantity of coke removed with the clinker before starting up, but as this coke can be burned under the boilers it is not lost. The quantity of clinker taken from the plant is small, and the clinker is soft and friable. The coke and clinker are separated by forking, and when conducting a test the coke is sometimes returned to the generator. It is generally used for steam raising. Coke is never mixed with the coal with a view to improving the working of the plant.

During the first part of the standover, a certain amount of rich gas is given off from the coal in the carbonization chamber. This gas is not lost, for as the stack valve is kept closed, it passes through the seal in the wash box into the relief holder. This circumstance complicates the conducting of tests on the plant when working intermittently.

The gas from the relief holder passes through a station meter so that the volumes are measured accurately. The volumes given in this paper are reduced to 60° F., saturated, and 30 inches pressure. Owing to the fact that the scrubbing and condensing plant was not built to meet the requirements of the complete gasification machine, it has not been

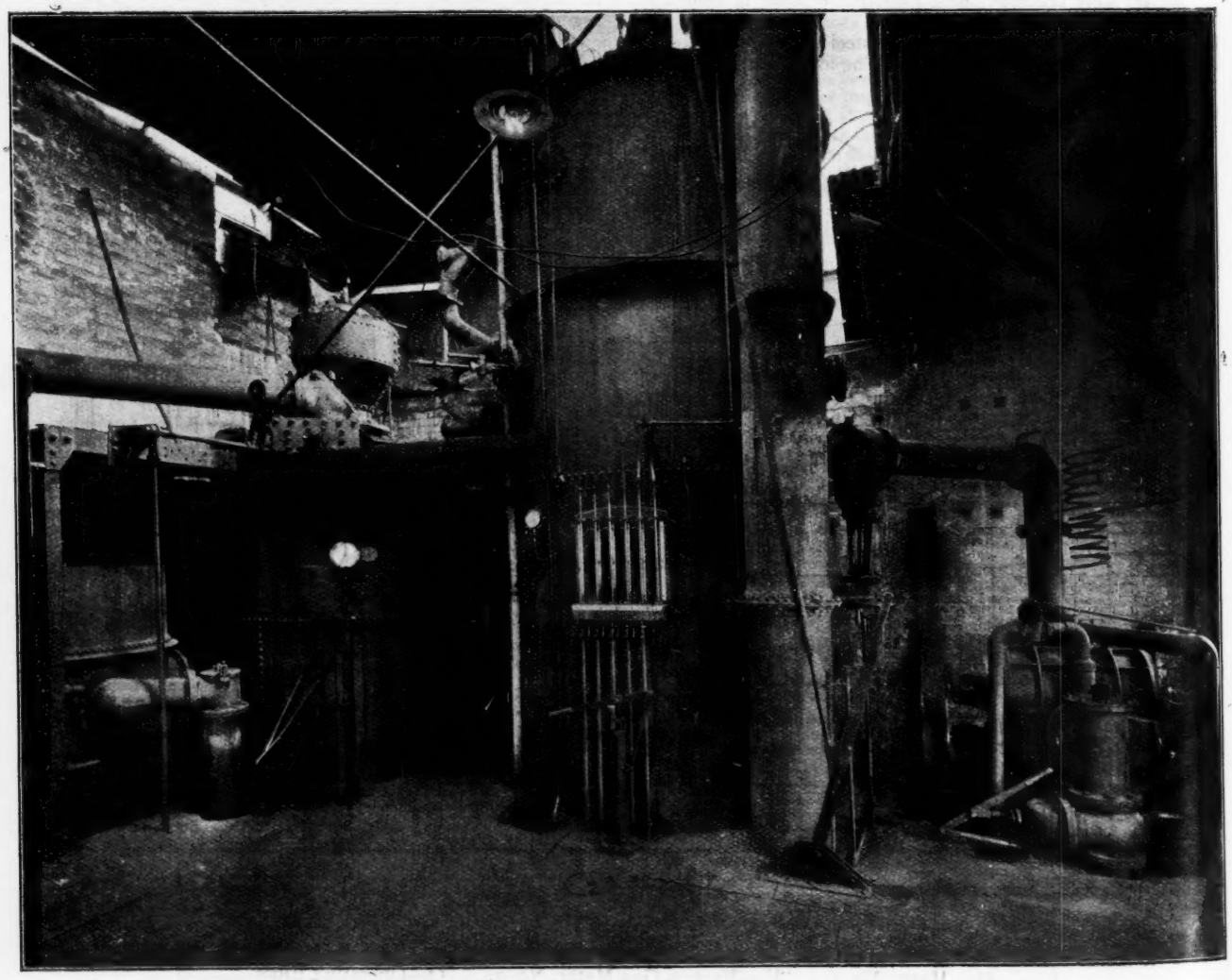


Fig. 2.—Operating Floor.

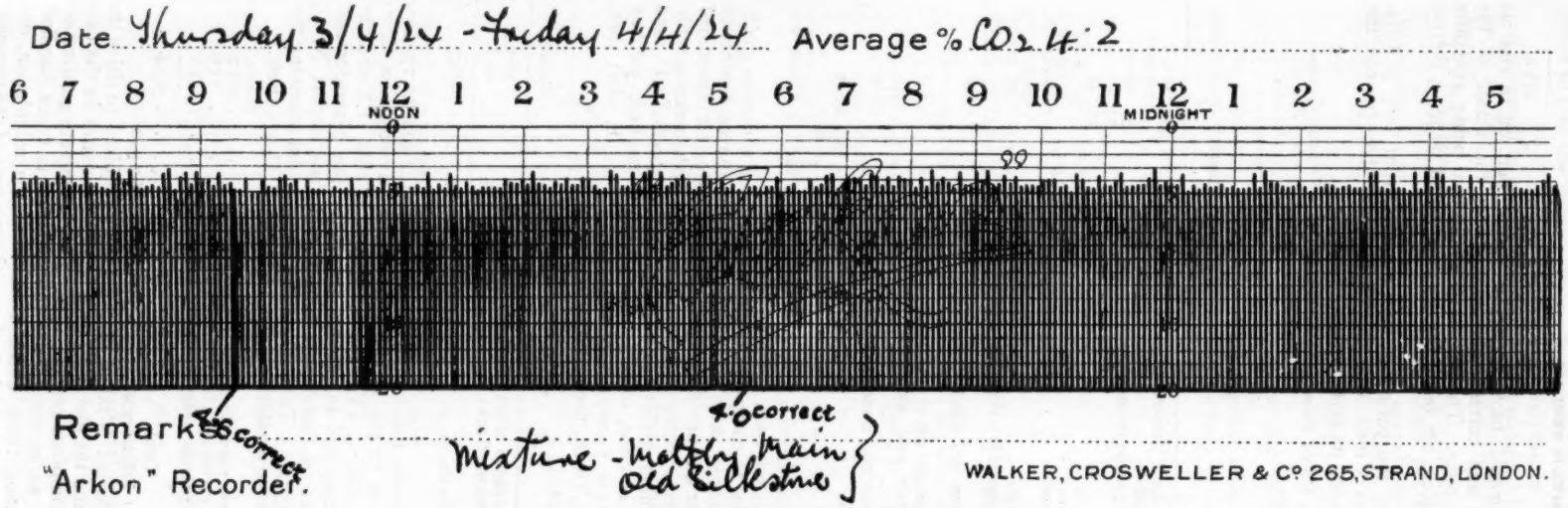

Date Thursday 3/4/24 - Friday 4/4/24 Average % CO2 4·2
6 7 8 9 10 11 12 NOON 1 2 3 4 5 6 7 8 9 10 11 12 MIDNIGHT 1 2 3 4 5
Remarks "Arkon" Recorder.
4·0 correct
mixture - Maltby Main
old Silkstone
WALKER, CROSWELLER & Co 265, STRAND, LONDON.

Fig. 3.—CO_2 Recorder Sheet (Actual Size).

possible to collect and measure the tar and liquor in such a manner as to provide even an approximate estimate of the output. It must not be forgotten that the quantity of coal used is very small compared with the large output of gas. The gas contains practically no naphthalene.

Owing to the conditions which have been referred to, it has been impossible to work the plant for more than a few hours a day, so that all the results of the tests so far carried out are for intermittent working. Experience indicates most clearly that, the shorter the standover period, the better are the results which are obtained, and the smoother the working of the plant. Nothing has occurred which would in any way suggest that continuous working would give rise to difficulties.

It was generally found convenient to enrich the gas from the plant up to a calorific value of 420 B.Th.U., and to mix it with an equal volume of gas from the intermittent vertical retorts of 520 B.Th.U., so supplying the district with gas at 460-470 B.Th.U. During a part of last year no oil was used in the plant, and during the month of July a test was carried out, using Maltby Main nuts, the results of which are given below. The test covered the periods Wednesday, July 11 to Saturday, July 14, and Tuesday, July 17, to Saturday, July 20.

The periods following the week-end standover were deliberately eliminated so that the observations could be made under conditions approaching normal working.

Total gas volume (corrected)	575,000 c.ft.
Coal gasified (3·5 p ct. moisture, 6 5 p.ct ash)	12·1 tons
Gas per ton of coal as handled	47,500 c.ft.
Gas per ton of dry coal	49,200 c.ft.
Gas per ton of dry, ash-free coal	52,800 c.ft.

A large number of determinations of the calorific value were made during the first period of the test, and the results are as follow :—

1923.	B Th.U
July 11—Morning	379·5
Afternoon	365·0
July 12—Morning	359·0
Afternoon	355·5
July 13—Morning	413·0
Afternoon	377·0
July 14—Morning	352·0
Average	371·5

The total volume of gas included the gas which came away from the plant during the night, amounting to upwards of 2000 c.ft. of a calorific value of 500 B.Th.U., each time the plant was shut down. The results are therefore:

	Therms.
Therms per ton from coal as handled	178·5
Therms per ton from dry coal	184·5
Therms per ton from dry, ash-free coal	198

In designing the present plant attention was concentrated on the arrangements for gasifying the coal, the efficient cracking of the oil being necessarily, under the circumstances, of secondary importance. Under the most favourable condition of continuous working the carburetting process could be carried out, even in the plant as at present constructed, with a fairly high degree of efficiency.

Working for about eight hours a day over a considerable period during the railway strike, without shutting down for week ends, the efficiency of the carburetting process appeared to be represented by about 0·8 therms per gallon of oil. Observations indicate that the efficiency increases as the daily period of running is increased, and also that it diminishes as the working is more intermittent. When running for short periods daily, and shutting down at week ends, it probably does not exceed 0·6 to 0·7 therms per gallon of oil.

However, observations of the working of the present plant have led to the design of an improved arrangement for carburetting, which has been patented by Messrs. Travers and Clark, Ltd.

It is by no means so easy to test the plant when carburetting the gas with oil. When not using oil it is possible to start up after the daily standover, increasing the period of the first blow to ten minutes, and then following the usual plant routine. When carburetting, the regenerator must be raised to cracking temperature before admitting oil, and steadied at that temperature. The usual practice, in order to save time, is to burn two or three runs of water-gas in the regenerator when starting up, but, as may well

be expected, this tends to give rise to local over-heating, and it is some time before a uniform temperature is established.

During the railway strike, between January 27 and February 9 of this year (1924), it was possible to run the plant every day for fourteen days for a period of eight hours a day, which is the nearest approach to continuous working so far attained. The coal was a mixture of Derbyshire and South Yorkshire coal averaging 4 p.ct. moisture and 6·5 p.ct. ash. Trinidad oil was used in quantity averaging 1·006 gallons per 1000 c.ft. (corrected) of gas made. The calorific value of the gas made averaged 440 B.Th.U., so that, as the gas from the coal alone has a calorific value of 360 B.Th.U., it can be assumed that 0·8 therm per gallon was being obtained from the oil. The result therefore is:—

Total gas made (corrected)	1,490,000 c.ft.
Coal gasified (4 p.ct. moisture, 6·5 p.ct. ash)	30·0 tons
Total therms	6,556
Less therms from oil	1,200
Therms from coal alone	5,356
Therms per ton of coal as handled	178·5
Therms per ton of coal, dry	186
Therms per ton of coal, dry, ash-free	199·5

It must be pointed out that the coke removed from the generator was not, in this experiment, returned to the plant. It amounted to about 0·1 ton per ton of coal. If this coke were converted into gas, and allowance were made for the addition, the figures given above could be increased by about 8 therms per ton of coal.

The plant ran for about eight months during last year. It was shut down late in the year for alteration, and was again started up again on Jan. 7 this year. Since that date it has been in constant operation, and the summary of the record of the working till April 30 gives a general idea of the manner in which it has been operated, and of the results obtained. It will be noted that the plant was shut down for 70 p.ct. of the total period, and at the week ends was generally shut down for 44 hours at a time. Occasionally it was worked for a short time on Saturday, and again for a short time on Sunday. It will readily be understood that such conditions do not make for economy.

In making the following calculations it is assumed that the gas from the plant would average 360 B.Th.U., and the carburetted gas 420 B.Th.U. over the whole period. The oil gasified works out at 0·87 gallons per 1000 c.ft. of gas over the whole period, so that the efficiency of carburetting is 0·7 therms per gallon. In heating up the plant rather more than three runs of water gas were burned every day, and as this gas contains some coal gas its calorific value is taken at 300 B.Th.U. per c.ft.

ACTUAL RESULTS OF A PERIOD OF FOUR MONTHS.

Total days Jan. 7 to April 30, 1924	115
Number of days on which plant was worked	104
Number of days (Sundays) on which plant was shut down	11
Average hours running on working days	7½
Average hours shut down on working days	16½
Length of standover at week-end	44
Coal handled	233 tons
Gas made	10,780,000 c.ft.
Gas made per ton	46,200 c.ft.
Calorific value	420 B.Th.U.
Therms	194
Oil used	9,380 gallons
Oil per ton of coal	40 gallons
Therms (0·7 per gallon) per ton of coal	28
Water gas burned	740,000 c.ft.
Water gas burned per ton of coal	3,176 c.ft.
Calorific value of water gas	300 B.Th.U.
Therms per ton of coal from water gas	9·5
Coke recovered (as before) per ton of coal	0·1
Therms from coke per ton of coal	8·0

The total therms obtainable from the plant per ton of dry coal are the sum of the three quantities:—

Therms from gas to holder	194·0
Therms from water-gas burned	9·5
Therms from coke recovered from plant	8·0
Total	211·5
Less therms from oil	28·0
Therms from coal	183·5

The actual therms from coal available as town's gas are found from the difference:—

	194·5
	28·0
	166·5

But the low result is practically due to the fact that on many Saturdays and Sundays the plant was run for between three and four hours, and to the practice of burning water gas in the plant as a means of speeding-up after the standover and before carburetting.

Thus:—

Therms in gas from coal as handled	166·5
Therms in water gas	9·5
Total	176·0

This would have been the output per ton of coal as handled, and corresponds closely with the result of the previous tests. The moisture in the coal being generally about 3 p.ct., the result for dry coal would be 181·5 therms per ton.

During the period of four months, from Jan. 7, 1924, two series of tests were carried out over short periods, the results being as given below:

A.—Using Maltby Main Coal (*Monday, Feb. 18 to Friday, Feb. 22*). (*Tuesday, Feb. 26 to Friday, Feb. 29*).
B.—Using Old Silkstone Coal (*Thursday, May 8 to Monday, May 12*).

—	A 3 P.Ct. Moisture. 6·5 P.Ct. Ash.	B 2 P.Ct. Moisture. 7·5 P.Ct. Ash.
Total gas made (corrected)	831,220 c.ft.	412,340 c.ft.
Coal gasified	16·4 tons	7·9 tons
Gas made per ton of coal handled	50,700 c.ft.	52,200 c.ft.
" " " " dry	52,300 "	53,300 "
" " " " ash free	56,000 "	57,730 "
Oil used	830 galls.	522 galls.
Calorific value	426 B.Th.U.	430 B.Th.U.
Total therms	3 531	1,773
Therms from oil (0·7 therm per gall.)	581	365
Therms from coal alone	2,950	1,408
Total therms per ton of coal handled	215	224·5
Therms from coal alone per ton handled	180	178
Therms from coal alone per ton, dry	185·5	181·5
" " " " " ash free	199	196·5

The coke removed from the generator was in these experiments put back again and gasified.

In order to compare the efficiency of the complete gasification process with the combination of the carbonization and water gas processes operated separately, if it is assumed that a coal is being dealt with which, on carbonization without steaming, yields 14,000 c.ft. of gas at 500 B.Th.U., and 13 cwt. of coke, of which 12·5 cwt. is gasified, yielding water-gas at 55,000 c.ft. of water gas per ton of coke; then, at 290 B.Th.U., the results are:

—	Gas.	Therms.
By carbonization of coal	14,000	70·0
By gasification of coke	34 375	99 7
Totals.	48,375	169 7

Taking the fuel required to carbonize the coal at 270 lbs. per ton at 12,460 B.Th.U. (see Gas Investigation Committee's Report IV., Trans. 1919-20, Table II.), and the energy required to provide steam for the generator and blower at 69 therms per ton of coke (see Report X, D, Trans. 1922-23, Table II. facing p. 322), and assuming the coal to have a calorific value of 12,800 B.Th.U., then:

	Therms.
From 1 ton of coal	286 7
To carbonize 1 ton of coal	33·6
To provide steam for blower and generator	43 1
Total	363·4
Efficiency of combined processes 46·7 p.ct.	

No account is taken of the energy required to drive the pumps and the elevating gear, which is greater in the case of the combined process than in the complete gasification process, as in the former the material is twice handled. Eliminating these extra items from the calculation, one would expect that, since the water-gas part of the complete gasification process is practically identical with the same process operated independently in the combined process, the total amount of energy brought into the system in the two cases should really differ only by the amount of the difference between the amount of heat required to carbonize the coal in the latter case, and the equivalent of the steam required to operate the circulator in the former case. On this basis

the comparison is in favour of the complete gasification process, but the considerations involved will now be discussed.

The output from the complete gasification plant approximates to

	Gas.		Therms.
Per ton of dry coal	49,000	..	184

The rate of steaming during the run period is 650 lbs. per hour, so that the steam supplied to the generator is :

$$650 \times 3 \times \tfrac{8}{5} \text{ lbs.} = 1220 \text{ lbs.} = 19{\cdot}3 \text{ therms.}$$

This result is in agreement with that obtained in the experiment described in the Gas Investigation Committee's Report X.D.

The circulator is driven by an old reciprocating engine, which probably absorbs 80 lbs. of steam per H.P. hour. When running at full speed, the engine cannot develop more than 5 H.P., and when slowed down it probably does not develop more than 2 H.P.

Taking the average power developed at $\frac{1}{2}(5 + 2)$ H.P., the steam consumed is :

$$\tfrac{1}{2}(5 + 2) \times 3 \times 80 \text{ lbs.} = 840 \text{ lbs.} = 13{\cdot}3 \text{ therms.}$$

This is probably an outside estimate.

The blower is driven by a De Laval turbine, and the energy consumed can be determined from the following data :

—	Running Full Speed and Blowing.	Slowed Down and Not Blowing.
Pressure at turbine . . .	55 lbs.	16 lbs.
Fan speed	1925 r.p.m	1080 r.p.m.
Air pressure	16 in.	4 in.
Air volume	2500 c.ft.	*Nil*
Brake horse power . . .	12·75	1·25
Steam per B.H.P. . . .	40 lbs.	60 lb.

The total steam consumed per ton of dry coal is :

$$(12{\cdot}75 \times 40 + 1{\cdot}25 \times 60) \times 1{\cdot}5 \text{ lbs.} = 877 \text{ lbs.} = 13{\cdot}6 \text{ therms.}$$

The total energy brought into the system is therefore :

	Therms.
1 ton of coal, as before	286·7
For steam to generator	19·3
For blower	13·6
For circulator	13·3
Total	332·9

Efficiency of complete gasification process . 55·3 per cent.

To be perfectly fair to the combined process, it may be taken to be conducted in such a manner that the steam to the circulator is reduced during the blow, which would slightly increase the efficiency.

APPENDIX 2.

Cost of Production into Holder.

Period—Jan. 7 to April 30, 1924.

		£	s.	d.
Hours worked	772			
Coal used	233 tons			
Gas made	10,780,000 c.ft.			
Calorific value	420 B.Th.U.			
Therms produced	45,276			
Oil used	9,380 galls.			
Operator—96·5 shifts at 8s. 4d. per shift . . .		40	4	2
Clinkering—32 hours at 1s. 2d. per hour . . .		1	17	4
Boiler (0·16 ton per ton of coal), 37·25 tons of breeze at 10s. per ton		18	12	10
Purification at 0·58d. per 1000 c.ft.		26	1	0
9380 gallons of oil at 4·5d. per gallon		175	17	6
Total cost		£262	12	10

Cost per 1000 c.ft., 5·85d.
Cost per therm 1·39d.

Gas Produced from Coal Alone.

Period—Jan. 7 to April 30, 1924.

		£	s.	d.
Hours worked	772			
Coal used	233 tons			
Gas made	10,302,000 c.ft.			
Therms produced	38,710			
Operator—96·5 shifts at 8s. 4d. per shift		40	4	2
Clinkering—32 hours at 1s. 2d. per hour		1	17	4
Boiler (0·16 ton per ton of coal) 37·25 tons of breeze at 10s. per ton		18	12	10
Purification at 0·58d. per 1000 c.ft.		26	1	0
Total cost		£86	15	4
Cost per 1000 c.ft.	2·02 pence			
Cost per therm	0·54 ,,			

Cost with coal at the following prices—

	Pence per 1000 C.Ft.		Pence per Therm.
20s. per ton	5·82	..	1·55
25s. ,, ...	7·18	..	1·91
30s. ,, ...	8·53	..	2·27
35s. ,, ...	9·89	..	2·63
40s. ,, ...	11·24	..	2·99

	s.	d.
Tar made (estimated) 10 galls. per ton of coal at 4·5d. per gall.	3	9
Ammonium sulphate made (estimated) 25 lbs. per ton of coal at £10 per ton	2	3
Total credit per ton for tar and ammonia . .	6	0

APPENDIX 1.

Approximate Analyses of Coals Used.

Name of Coal.	Wet Basis.				Dry Basis.		
	Moisture.	Volatile M.	Ash.	Fixed Carbon.	Volatile M.	Ash.	Fixed Carbon.
	P.Ct.	P.Ct.	P.Ct.	P.Ct.	P.Ct.	P.Ct.	P.Ct.
Maltby Main	3·0	30·2	6·5	60·3	31·1	6·7	62·2
Old Silkstone	2·0	29·8	7·5	60·7	30·4	7·7	61·9

Gas Analyses.

Test.	CO_2.	C_mH_n.	O_2.	CO.	CH_4.	H_2.	N_2.	Total Inerts.	Calorific Value.	
									Calculated.	Actual.
	P.Ct.	P.Ct.	P.Ct.	P.Ct.	P.Ct.	P.Ct.	P.Ct.	P.Ct.		
A. . .	4·6	2·0	*Nil*	32·2	15·4	38·4	7·4	12·0	431	426
B. . .	6·2	2·2	*Nil*	27·2	15·0	40·2	9·2	15·4	422	430
C. . .	5·5	0·8	*Nil*	28·0	9·5	49·0	7·2	12·7	361	—

C. is the average analysis of a number of samples of the gas when no oil was used.

Factors used for calculating calorific value.

C_mH_n . . . 2660 B.Th.U. per c.ft.
CO . . . 318 B.Th.U. per c.ft.
CH_4 . . . 992 B.Th.U. per c.ft.
H_2 . . . 320 B.Th.U. per c.ft.

Trinidad Gas Oil.

Specific gravity at 60° F. . . . . 0·8610

Distillation (by weight).	P.Ct.
158-200° C.	8·6
200-310° C.	51·4
310-360° C.	30·0
Above 360° C. (coke)	10·0
	100·0

COMMUNICATION BY DR. M. W. TRAVERS, F.R.S., IN OPENING DISCUSSION ON PAPER ON "THE REGENERATIVE COAL GASIFICATION SYSTEM AT AYLESBURY," BY MR. A. G. LANE.

In a paper published in the "JOURNAL" for Oct. 3, 1923, p. 34, Mr. F. W. Clark and I dealt with the theory of our new process for the complete gasification of coal. We showed that, in order to gasify coal completely, by a method based upon the water-gas process, it was necessary to supply more heat to the coal in the process of gasification than was available as sensible heat in the water gas produced from the coke. To make up the deficiency, the regenerative system was applied to the carbonization process; heat being recovered regeneratively from the waste, or blow, gas by means of mixed water gas and distillation gas circulated through the coal at a rate which could be controlled. In the same paper we described the plant which we had erected at the Aylesbury Gas-Works, and gave a preliminary account of the results of the first eight months' working. It is only two years since we commenced the theoretical investigation of this process, and less than eighteen months since the first plant was actually started-up. In that time we have made some progress in developing our process, and the results of the operation of the Aylesbury plant under practical, if not under ideal conditions, as set forth in Mr. Lane's paper, prove that the regenerative system, as a method of completely gasifying bituminous coal, is a practical proposition. From our point of view, that is what the Aylesbury plant was intended to prove or disprove. However, but for the invitation of your President to take part in this discussion, we should not, at this stage, have published a further communication on the subject.

I do not propose to discuss the results contained in Mr. Lane's paper in detail, and perhaps I need hardly point out that, with the first plant which we constructed, operated intermittently in accordance with the practical requirements of the gas-works, and on no occasion operated under test conditions, the best results were not likely to be obtained. Further, as the plant was designed with a view to testing the regenerative system of complete gasification, we were obliged to concentrate attention on this process, and to regard the carburetting of the gas as a side issue.

Since the plant has been in operation, we have spent a great deal of time at Aylesbury, and thanks to the courtesy of the Gas Company and their staff, who have rendered us every assistance, we have been able to make a thorough study of the process. As a result, we are fully acquainted with any difficulties which have arisen in the operation of the original plant, and now see our way to rectify existing defects and to increase the efficiency of the process, particularly so far as the carburetting of the gas is concerned.

The design of such a plant as we are considering, if success is to be achieved within reasonable time, must be based upon the practical experience gained in the study of similar processes, combined with the knowledge of the theoretical principles involved. In our complete gasification plant four processes, each of which may be regarded as operating separately, take place:

I. The carbonization process.
II. The water-gas process.
III. The regenerative process.
IV. The carburetting process.

We will deal with each process in some detail.

It is not an easy matter to study the process of carbonization in the plant, for there is no means of withdrawing solid material from the region in which it takes place. If the generator is kept full of coal, and the rate of circulation of the gas from the regenerator is maintained so as to carry sufficient heat into the carbonization section of the plant, the blow gas is clean and free from smoke, indicating that the coke entering the gasification section of the plant is free from volatile matter. In actual operation, the circulation gas is rarely heated in the regenerator to over 850° C.; the water gas generated from the coke passing into the carbonization section at a somewhat higher temperature, so that the highest temperature reached in the carbonization process is about 900° C. However, if this temperature is actually reached, it may be concluded from the results of observations on the working of steamed vertical retorts that the carbonization of the fuel would be carried out effectively. In plant of the latter type, the steam acts on the hot coke, producing water gas; and when the quantity of steam passed into the retorts is of the order of 10 p.ct., calculations based upon the water-gas equilibrium indicate that the temperature in the body of the charge reaches, at a maximum, about 900° C. At the same time, apart from the chemical action of the steam, steaming appears to facilitate the decomposition of the coal and the removal of the volatile constituents; and the circulation of the mixture of coal gas, water gas, and water vapour through it will probably have a similar result. In some respects the process may be more closely comparable to that taking place in the steam-blown gas-producer, in that the distillation gases do not pass through a region of temperature higher than that of the coal. However, as most of the gas passes through the regenerator, fixing of hydrocarbons of comparatively low molecular weight is probably effected in this manner.

The water-gas process in the gasification section of our plant appears to proceed normally, so far as the word "normal" can be applied to a process, the course of which is dependent upon so many factors. During recent years a great deal of experimental work, both on industrial plant under working conditions and in the laboratory, has been carried out with a view to elucidating water-gas problems. For the former we are indebted to the Institution of Gas Engineers (Reports Nos. VI., VII., and X.), the Fuel Research Board (Technical Paper No. 6), the Engineering Experimental Station of the University of Illinois, and the American Bureau of Mines. In connection with the latter I should refer in particular to recent work on the use of bituminous fuel in water-gas plants, and to the well-known Technical Paper No. 137, which tells us almost all we know about the gasification of coke by air in the fuel bed. Careful analysis of the published results of tests of water-gas plants show that much yet remains to be done; and no results yet published tell more than that a particular plant gives the best results under particular conditions. Comparing, for instance, the results of the experiments described in Report VI. of the Institution, with experiment D of Report X., one can assign no reason for the fact that in the latter 10 p.ct. more water gas was obtained than in the former. I must also point out that, while the efficiency of the production of water gas depends mainly on the efficiency of the blow process, published experimental work is mainly defective in that the most important factor, the quantity of primary air supplied to the plant, is not measured, so that the consumption of carbon in the blow process is only determined indirectly. Experiments, in which the blast velocity and blast period were varied, the air being measured, and other factors being kept constant, would be of great value. In the practical operation of water-gas plants it is obviously essential to be able to supply a definite quantity of air to the generator during each blow period. It is really not very easy to carry this idea into actual practice, but as a step in this direction we are now installing blowing plant with two fans driven by a turbine; one fan supplying the primary air to the generator, the other the secondary air to the regenerator and carburettor.

From the purely scientific standpoint, there are no recent researches which really throw much light upon the mechanism of the blow process, so we must fall back upon experimental evidence such as that contained in the paper by the American Bureau of Mines, already referred to, or to investigations such as those of Wendt (Stahl und Eisen, 1902); bearing in mind the fact that they all relate to the continuous blowing of the fuel bed, and not to the intermittent process as operated in the water-gas cycle. I think, however, that it can be assumed that the two main reactions which operate are represented by

$$C + O_2 = CO_2, \text{ and}$$
$$CO_2 + C = 2\,CO.$$

The former is the main reaction taking place in the extreme lower layers of the fuel bed, and is dominant till, at a very few inches above the firebars, the oxygen disappears. As the oxygen disappears, the second reaction comes into play at a rate which is probably materially affected by the ash in contact with carbon. It helps one to realize what is taking place in the fuel bed if one keeps clearly in mind the fact that the fuel bed in actual practice is a very irregular structure, that along any one vertical line the gas may travel for a considerable distance at a high velocity without actually coming into contact with carbon at all, and that along another it is travelling through a restricted channel in intimate contact with the coke. This is an extreme case of

heterogeneous reaction, and such terms as the rate of reaction must be used very guardedly. However, the practical result of all experience is that on the one hand, when the rate of flow of the gas through the fuel bed is low, the equilibrium condition corresponding to very low CO_2 content in the gas is readily attained; the product being a mixture of nitrogen and carbon monoxide, with very little carbon monoxide. When the blast velocity is high, so long as the fuel bed is free from holes, the CO_2 content of the gas does not rise to much above 15 p.ct., and the results claimed for the Dellwik process can only be accounted for, as Dr. Parker points out, by irregularities in the fuel bed.

The run process has been the subject of several recent investigations, all of which relate, however, rather to gas-producer than to water-gas practice, in that the upper limit of temperature of the experiments was generally much lower than that at which a water-gas plant operates. Among the most important of these are the researches of Gwosdz (Zeit. Ang. Ch., 1918, **31**, 1,137), Taylor and Neville (Am. Chem. Soc. J., 1921, **43**, 2055), Kohn (J. Ind. and Eng. Ch., 1922, **14**, 69), and Haslam, Hitchcock, and Rudow (J. Ind. and Eng. Ch., 1923, **15**, 115). These investigators agree only as to certain particulars, which relate, unfortunately, to conditions of temperature below the range which is of much importance in considering the water-gas process. It is generally agreed that the reaction

$$\text{I.} \quad C + 2H_2O = CO_2 + 2H_2$$

is the dominant reaction at low temperatures, and that it represents what takes place in the lower part of the fuel bed, where much carbon dioxide is produced. As the gas passes into the region of very high temperature, the carbon dioxide is reduced in accordance with the equation

$$\text{II.} \quad CO_2 + C = 2CO;$$

but in this reaction, in which a gas and a solid are involved, equilibrium which corresponds to the almost complete removal of the CO_2 is never reached. On the other hand, equilibrium in the system

$$\text{III.} \quad CO + H_2O = CO_2 + H_2,$$

in which the reacting substances are entirely gases, is very rapidly attained, particularly owing to the catalytic action of the free ash in the fuel. The result is that the ultimate CO_2 content of the water gas is determined by the excess of steam, and excessive steaming gives rise to high CO_2 concentration in the gas, a circumstance to which British gas engineers pay more attention than do their American colleagues. It must be admitted that the results of all these investigations do not enable us to lay down exact rules for the operation of water-gas plants, and that with a particular plant, using a particular fuel, the depth of fuel bed, the operating cycle, and other factors upon which efficiency ultimately depends, must be determined by actual trial.

The regenerative and carburetting processes call for careful attention. We may consider the changes taking place in them as represented by the following equations, which are written so as to indicate that change in equilibrium with rise of temperature takes place in the direction from left to right:

A. $CO_2 + H_2 \rightleftharpoons CO + H_2O - 10{,}105$ C.H.U.

B. $CO_2 + C \rightleftharpoons 2CO - 41{,}100$,,

C. $CH_4 + H_2O \rightleftharpoons CO + 3H_2 - 51{,}365$,,

D. $CH_4 + CO_2 \rightleftharpoons 2CO + 2H_2O - 61{,}470$,,

E. $CH_4 \rightleftharpoons C + 2H_2 - 20{,}360$,,

F. $C_2H_4 \rightleftharpoons CH_4, C, H_2$

G. $C_2H_6 \rightleftharpoons CH_4, C_2H_4, C, H_2$

The changes represented by these reactions may be generally assumed to take place only in contact with solid surfaces, at least within the limits of temperature attained by the circulation gas. If the regenerator is kept at a temperature not above 850° C., this may possibly be considered the upper limit of temperature at which change takes place in the gases, since the brickwork at that temperature would probably be a more active catalyst than coke at a somewhat higher temperature. In the run process operating in the generator, it appears that the water-gas equilibrium (equation A) is established in the neighbourhood of 1300° C., and does not become reversed in passing through the coke and semi-carbonized coal in the upper layers of the fuel bed. Yet we had reason to fear that, were we to pass the gas, with the moisture content with which it would leave the generator, through the regenerator, the CO_2 content might be increased unduly.

Supposing that the dry gas had the composition shown in column I. of the following table, with increasing saturation temperature—that is to say, with increase of the temperature at which it left the condenser and entered the circulator—the composition would change as indicated in the succeeding columns.

	I.	II.	III.	IV.	V.
Saturation temperature	Dry	25° C.	35° C.	45° C.	55° C.
Vapour pressure water (mm)	0·0	23·8	42·2	71·9	118
H_2O p.ct.	0·0	3·13	5·15	9·46	15·54
CO_2 ,,	5·0	4·85	4·72	4·52	4·22
C_mH_n ,,	0·8	..	..	..	..
CO ,,	28·0	27·13	26·46	25·34	23·66
CH_4 ,,	9·0	..	..	..	..
H_2 ,,	50·0	48·45	47·25	45·25	42·25
N_2 ,,	7·2	..	..	..	..
Log $\frac{P_{CO} \times P_{H_2O}}{P_{CO_2} \times P_{H_2}}$	..	−0·456	−0·185	0·071	0·313

The value of Log $\frac{P_{CO} \times P_{H_2O}}{P_{CO_2} \times P_{H_2}}$ corresponding to equilibrium conditions at 800° C. is 0·06, and at 900° C. is 0·10, so that if the dry gas had the composition given in column I., the saturation temperature of the wet gas entering the regenerator might be allowed to rise as high as 45° C. (113° Fahr.) without risk of increasing the CO_2 content through reversal of the water-gas reaction. In the case of a gas of lower hydrogen content, the limiting temperature is also lower. Very efficient condensation of the gas is therefore not really necessary to overcome this apparent difficulty. The result indicated above has been fully confirmed by actual experiment.

Reaction B is of the greatest importance in connection with the formation of carbon monoxide in the blow and run processes, but of very slight importance so far as reactions taking place in the circulation process are concerned.

Reactions C and D received a good deal of attention in connection with the carbon-monoxide controversy last year, but they are of little real interest to the gas maker. To convert the carbon monoxide and hydrogen in town gas into a mixture of methane, carbon dioxide, and water vapour would be thermally expensive, and practically futile. The conversion of carbon monoxide to methane can be effected in presence of metallic catalysts, such as nickel, at low temperatures, almost quantitatively; but the reaction appears to take place only very slowly in contact with brickwork. At temperatures over 600° C., equilibrium conditions correspond to the practically complete conversion of the methane into carbon monoxide, but owing to the stability of methane the extent of this change is not appreciable.

The carburetting process, and the general questions relating to the cracking of hydrocarbons by heat, are the subject of very extensive literature, the contents of which, so far as they have any direct bearing upon the subject, may be summed-up briefly. The study of the subject goes back to the days of John Dalton, but one may omit reference to work earlier than that of Bone and Coward (J. Chem. Soc., 1908, 93, 1197), who showed that the time factor was of first importance in dealing with the decomposition of hydrocarbons by heat. In the case of methane, equilibrium conditions should correspond to decomposition of pure methane to an extent indicated in the following table.

Temperature.	Methane Remaining in Methane-Hydrogen Mixture.
°C.	P.Ct.
700	11·1
800	4·4
900	2
1000	1

However, when the gas was actually maintained in an empty silica tube for one hour, the extent of decomposition was relatively small even at 1000° C.

Temperature °C.	785	1015	1150
Methane decomposed, p.ct.	4·4	35·0	83·3

Other hydrocarbons are more readily decomposed, as the following table indicates.

Hydrocarbon.		Ethane (C_2H_6).		Ethylene (C_2H_4).	
Temperature ° C.		800	1000	800	1000
Time, minutes		15	5	15	5
Product	C_2H_2	0·5	0·55	3·85	0·35
	C_2H_4	0·75	1·80	9·65	1·65
	C_2H_6	..	1·15	1·30	..
	CH_4	64·65	41·95	64·45	48·35
	H_2	34·10	54·55	20·75	49·65

In each case it will be noted that the main product is the stable methane, so that in mixtures of hydrocarbons, subjected to high temperatures, the amount of methane in the gas may be maintained or even increased by the decomposition of more complex hydrocarbons. The semi-quantitative experiments of Slater (J. Chem. Soc., 1915, 160) also demonstrate the extraordinary stability of methane.

Two very elaborate series of experiments on the cracking of hydrocarbons have recently been carried out by Whitaker in America. One with Alexander (J. Eng. and Ind. Chem., 1915, 484) on the "time factor in the production of oil gas," and one with Leslie (*ibid.*, 1916, 593 and 684) on the "decomposition of hydrocarbons and the influence of hydrogen in carburetted water-gas practice." The conclusions which can be drawn from these experiments may be summarized as follows:

I. In actual practice equilibrium is never reached in the thermal decomposition of hydrocarbons.

II. Hydrocarbons decompose in accordance with the laws of chemical dynamics; the quantity of each substance which changes or is decomposed in unit time depending on the quantity of it which is present.

III. Hydrogen has no influence on the primary decomposition of paraffin hydrocarbons, which yield in the first place methane and olefines.

IV. Hydrogen reacts with the olefines; the amount of hydrogen absorbed increasing with hydrogen concentration and with rise of temperature.

V. Little tar is formed below 725° C., tar formation is at a maximum near 800°, but decreases at higher temperature.

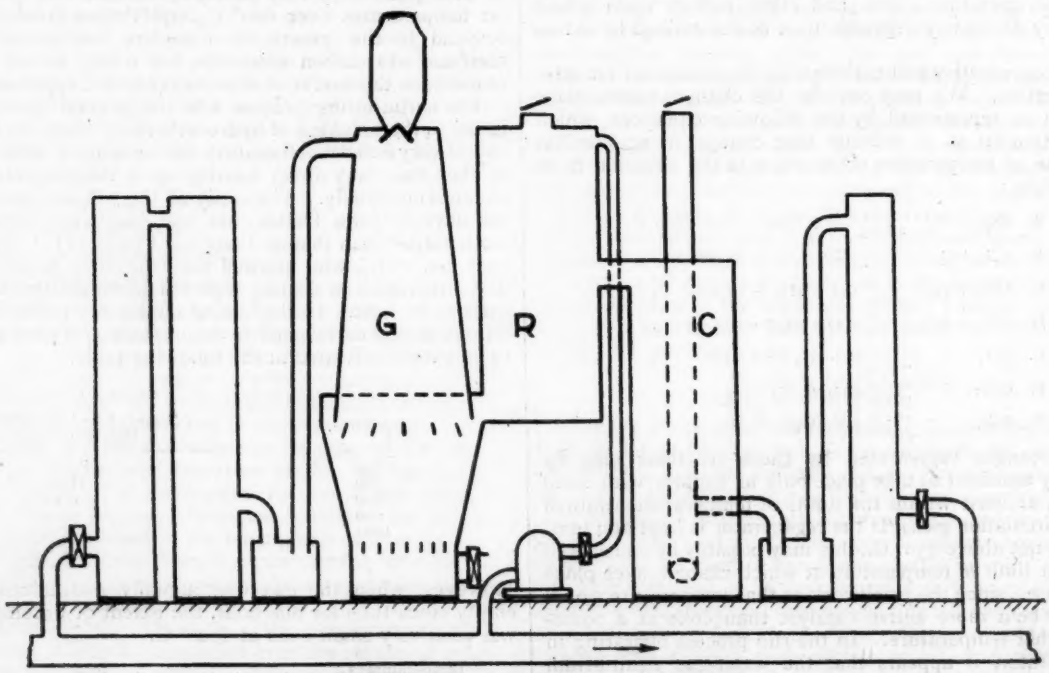
In carburetting water gas with oil consisting mainly of paraffin hydrocarbons of the general formula C_nH_{2n+2}, which actually approximates to C_nH_{2n} when the value of n is large, the ultimate products of the decomposition of the oil are methane, with lesser quantities of the higher paraffin hydrocarbons, C_2H_6, &c., unsaturated hydrocarbons of the general formula C_mH_n, where the average value of m is about 3, tar approximating to the formula $(CH)_n$, and free carbon. The methane and the small quantity of gaseous paraffin hydrocarbons accompanying it contain relatively more hydrogen in relation to the carbon than the original oil, and this hydrogen must be derived from the water gas, or gained at the expense of the formation of tar and free carbon. What actually happens in practice is indicated by the following analysis of the results published in the Seventh Report of the Institution. The average of the results of the experiments described in this report show that 840 c.ft. of blue water gas (282 B.Th.U.) carburetted with 2·28 gallons of oil, yielded 1000 c.ft. of carburetted water gas (483 B.Th.U.).

—	Blue Water Gas.	Carburetted Water Gas.	Increase or Decrease.
	C.Ft.	C.Ft.	C.Ft.
CO_2	51·24	53·0	+ 1·76
C_mH_n	0 0	59	+ 59
CO	324·24	347	+ 22·76
CH_4	4·20	100	+ 95·8
H_2	433·44	383	− 50·44
N_2	26·88	54	+ 27·12

The figures show that in actual practice a considerable amount of hydrogen is taken up in the formation of hydrocarbons, and that some steam also takes part in the reaction. In these experiments the temperature could be controlled fairly accurately, but the time which the oil remained in contact with the hot brickwork, and the relative proportion of the oil and water gas, are practically dictated by the design of the plant. Yet the efficiency of the carburetting process is high.

The efficient cracking of the oil for the carburetting of the gas is a problem which we were obliged in the first instance to regard as of secondary importance to that of the regenerative gasification of the coal. In the Aylesbury plant the oil is injected into the regenerator, which is not built exactly as shown in the drawing in Mr. Lane's paper, so that the oil spray meets hot circulation gas. The mixed circulation gas and oil gas pass through the regenerator and mix with the water gas in the generator. In this system it is not possible to control effectively the rate at which the gas passes through the regenerator, the relationship of the oil to the circulation gas, or the temperature at the hottest point of the circuit, which must be that required to gasify the coal, and therefore too high for efficient oil cracking. Since the rate of decomposition of olefines increases rapidly from 800° C., and since the quantity decomposed increases with the increase in the quantity present, or first formed from the oil, the process becomes less efficient the larger the quantity of oil used. The gas can be enriched up to 450 B.Th.U. fairly efficiently; but for the production of a richer gas we propose to modify our plant in a manner which would appear to be obvious, and which is protected by English Letter Patent No. 210356.

In this process we construct, in addition to the regenerator R, a second vessel or carburettor C, connected with the

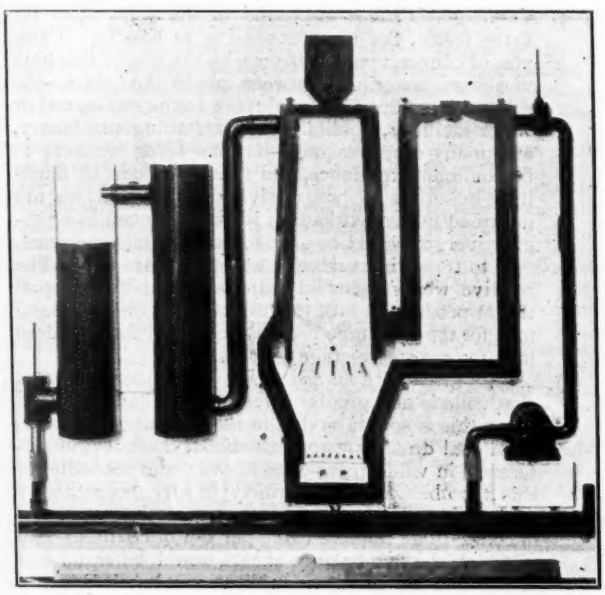


DIAGRAMMATIC REPRESENTATION OF PLANT.

regenerator at some distance from entry to the generator G. During the run, the circulation gas enters the top of the regenerator. Part of it passes to the bottom and into the generator, and part of it enters the carburettor, into the top of which oil is sprayed. The carburetted gas leaves the carburettor through a washer and special condenser, and passes to the main leading to the gasholder through a special control valve, by means of which the flow of circulation gas into and through the carburettor is regulated. The circulation gas is drawn from the main at a point more distant from the relief holder than that at which the carburetted gas re-enters it. So long, therefore, as the amount of gas passing through the carburettor does not exceed the amount produced in the generator, the circulator will take up no carburetted gas, which, in consequence, will not pass through the regenerator and generator. During the blow, the blow gas flows through the regenerator and carburettor, escaping by the two stack valves in proportions that can be regulated. Secondary air can be admitted to either or both vessels. By this means the rate of flow of the gas and the rate of flow of the oil into the carburettor, and also the temperature of the latter, can be regulated so that we have control of all the factors which theory and experience show to be the requirements of efficient carburetting.

Model of Complete Gasification Plant.

The model shows the plant in its simplest form in vertical section, the front being formed of plate glass so that



Model of the Complete Gasification Plant, operated with Water and Coloured Liquids, illustrating the Working of the Regenerative Process.

coloured liquid can be passed through it for the purpose of demonstrating the operation of the blow, run, and circulation process. The particular object of the demonstration is to show that the quantity of gas circulated through the regenerator and the carbonization section of the generator is quite independent of the quantity of gas generated. The circulation may indeed be maintained equally rapidly when steam in being blown into the generator, and when the steam is cut off. This being the case, it is shown that a quantity of heat largely in excess of the sensible heat of the water gas generated can be carried from the regenerator to the coal in the carbonization section of the generator.

By Mr. F. W. Clark, M.I.Mech.E.

Members of this Institution, and particularly those who have been closely connected with the introduction of new plant or processes, may best appreciate our communication, if, instead of laying particular emphasis on the merits of this system, we bring before you what appear to us to be some of the more basic considerations involved in this process for the manufacture of town gas by an apparatus which, for convenience, may be considered as coming under the general title of complete gasification plant. We would, however, like to add that, after some two years' study of the question, and extended experience of work on practical plant under daily operation in gas-works, we are of the opinion that, if any excuse is required for our accepting your invitation to communicate this note, it is supplied by the experience of the past two years, which has shown that this process has at least the merit of a sound basis upon which progress and development may rest. As Dr. Travers also tells you, but for the invitation of your President we should not have published anything further at the present time.

Bearing in mind the history of the complete gasification of coal, we propose to examine, in the light of theory, and experience of analogous operations, some of the more basic considerations involved in this highly technical problem. To-day, therefore, instead of pretending that we are giving a description of a perfected process, or of an apparatus in which that process is carried out, we shall attempt to describe the principles involved, and to tell a plain tale of what has been done so far, leaving—except for a brief reference—future plans for the development of our plant for description at a later date.

In the development of a new process, it is interesting to study the results obtained from time to time, so as to follow the progress of improvement. In the present instance I need only call your attention to the fact that, in plant of this type, the longer the running period, the smoother the working and the higher the efficiency. The results which we have so far recorded are but the averages of a few hours' working each day, and generally for weekdays only, and they include the unavoidable losses due to the need for warming up the plant after the long daily stand-over, and particularly after the longer idle periods at week-ends. When plants are running continuously, and under conditions approximating to test conditions, it may be anticipated that the results recorded for the periods of longer working hours will be improved upon.

As a two-stage process, the complete gasification of coal is, of course, carried out to-day in many gas-works; for were it not so, the selling price of coke would probably vary from that now actually received. And if, in the disposal of coke, the same laws of supply and demand hold good as for other products of commerce, it is not unreasonable to doubt whether the total receipts from the home market would be much greater than the value at present received for the lesser weight. Whether variation in the form (gaseous or solid) in which the sale of therms is carried out to-day would result in greater efficiency, more general convenience, or greater profit will always be an interesting question absorbing your constant attention; and perhaps it has no final solution other than in the constant adjustment of ever-changing conditions to ever-varying demands. Looked at as a whole, it may justify the well-known observation that "whatever *is* is right," though the writer of the words does not appear to have studied the science of engineering.

Within this larger question is the smaller and highly technical one of the advantages of a one-stage process as compared with a two-stage one, as generally operated to-day. The development of the former will probably both influence and be influenced by the way in which the larger question is handled. It is with the technical considerations of the single-stage process only that we have concerned ourselves in preparing this communication.

The design of single gas-making plant that shall fulfil all the exacting requirements of your industry is not without considerable difficulties; for, to be successful, the designer must meet the demands of to-day and be not unmindful of the requirements of the future. The average calorific value of the gas required to-day necessitates that, for the design of a successful single-stage gas machine, not one process, but four processes must be studied; and Dr. Travers very briefly refers to the considerations involved, and shows how, in the Regenerative Coal Gasification System, in one machine, in one operation, and worked by one operator, gas of a calorific value equal to the average declared value of to-day is manufactured direct from coal, steam, and oil. I will return to this point of the relation between the single and double stage processes, but should here like to add a note on the principle underlying our system.

In our communication of October of last year [see "Journal" for Oct. 3, 1923] describing the investigation upon which this system was subsequently based, it was shown that the highest thermal efficiency as expressed by the formula

$$\frac{\text{Heat in gas} \times 100}{\text{Heat in coal}} = \text{Thermal efficiency p.ct.}$$

was obtained by the producer-gas process, wherein the exothermic and endothermic reactions are so balanced that it is possible to produce gas continuously by the simultaneous action of air and steam on coal. We also explained how the Regenerative Coal Gasification System applied the principle from which the producer-gas process derives its high thermal efficiency to the production of a gas that meets the requirements, restrictions, and regulations of town supply.

In the producer-gas process the volatile constituents are driven out of the coal by the direct application of sensible heat carried into and through the coal by the gases rising from the gasification zone below; and nature has decreed that, owing to the extremely large nitrogen content in the air employed, the sensible heat of the gases passing into the coal is necessarily very large, being some four times the amount that would pass through the coal superimposed over a water-gas generator. In the Regenerative Coal Gasification System the gas produced, being substantially free from nitrogen and other inerts, and correspondingly smaller in volume, is circulated any number of times through the coal, being previously re-heated by means of a special regenerator, the energy for the re-heating process being supplied by the waste heat of the blow. The energy of the waste blow gases is thus passed direct to, and into direct contact with, the coal, doing work thereon, with the result that the volatile constituents of the coal are liberated or driven out. In passing, I would draw your attention to the interesting point that the amount of heat passed into the coal during the gas-making period or "run" is much in excess of the sensible heat of the gases produced during the same time, so that the process is hurried forward during the run.

It will be noticed that the difference between the producer-gas process and the Regenerative Coal Gasification System is that, in the former, the energy from the exothermic reaction of the air with the fuel, which takes place simultaneously with the endothermic reactions due to steaming, is applied directly, whereas in our process this energy is applied indirectly by means of regeneration. The comparative results of this direct and indirect application of the same principle show that the high percentage of inerts in the producer-gas process is avoided in our system, and consequently the gas made in our gas-machine is of a much higher calorific value.

In the foregoing comparison it has been convenient to use the word "indirect" when referring to the method by which the energy is conveyed from the hot waste gases to the coal under treatment by the regenerative process, but, compared with retort carbonizing processes, the energy is, of course, applied direct to the coal.

In the design of gas-making plant, the direct application to the coal of the energy in the heating gases appears to have many advantages, one of the chief being a simplification of plant. The mere comparison of the terms "indirect" (the retort process) and "direct" suggest some of the possibilities, for it is at once seen that, in the latter, the whole of the walls which form the containers for the coal under heat treatment in the retort process, together with their surrounding flue passages, are unnecessary, and, further, in the conservation of heat, the more complex and less efficient recuperative method gives place to the simpler and more efficient regenerative system. I should like to make it clear that in the Regenerative Coal Gasification System no retort is used; the whole of the heat treatment of the coal being by direct heating.

It is interesting to note that in a design of a modern vertical-retort plant recently examined, the space occupied by the flues surrounding the retorts, and the retort walls only (exclusive of all walls outside of the flue space surrounding the retorts), is four times as large as the space occupied by the coal. By the direct application of heat to the coal, the whole of this flue space and the space occupied by the retort walls is, of course, avoided; and as their upkeep forms the main item of cost in the repair bill for retort plant, their entire elimination wipes out the whole of this item. In passing, I would like to add that this point in the comparative merits of the single and two stage methods should not be lost sight of. Practically the cost of repairs to that part of a single-stage machine in which carbonization of the coal is effected by direct application of heat must necessarily be but a small fraction of that for the ordinary retort plant.

The following would appear to be some of the chief points of interest in any comparison made between the single and double stage process:—

(1) *Capital Outlay* per therm produced is of the order of 3 to 5; the single-stage process being represented by the lower figure. If the comparison is extended to include the buildings, it is still more favourable to the single-stage process.

(2) *Ground Space.*—The single-stage process occupies much less ground and requires smaller buildings. An actual case may be cited of a plant under construction. The building contained inclined retorts which actually produced an average of 2750 therms and a maximum of 3000 therms per diem. Without any alteration to the building, 15,000 therms per diem will be made if the condensing and scrubbing plant is located within the building, and 20,000 therms if the building is utilized for generating plant only.

(3) *Labour Employed.*—This may be stated in various ways, and depends on the size of the units taken for comparison. However, considering the actual gas-making operations only, a fair comparison may be readily made. In the two-stage process a certain number of men will be employed on the first (carbonizing) section of the work, and a smaller number of men, usually about one-half (or one-third of the total), upon the second section of the two-stage process. The total labour expended on the single-stage process will be the same as the second section only of the double-stage process.

(4) *Handling Materials.*—Material in the solid is, of the three forms, the most expensive to handle. There are, of course, many reasons why the cost of this item varies so materially between place and place—the relative location of the coal mine to the works, rail or water facilities, possibilities of installing machinery, and many other reasons—but one thing appears to be common experience, and that is the cost of handling materials is progressively rising, and we are informed in gas-works that it has advanced in a progressively upward line until to-day it is, in some cases, two to three times what it was ten years ago. The relative weight of solid material to handle for equal therm production is of the order of over one thousand tons for the two-stage process and under four hundred tons for the single-stage process.

(5) *Relative Prices of Coal and Coke.*—It frequently occurs that coke is of a greater value per ton than coal; and when this is so, the saving in the manufacture of gas from coal direct is twofold. First, there is the difference in value mentioned above; and secondly, to this is to be added some thirty to fifty more therms of gas obtained from one ton of coal than from one of coke. The relative value per ton of coal and coke at which the two balance-sheets would be equal will probably differ in every application; but it appears that, taking into account the various and many items concerned, it is fair to suggest that it is more economical to manufacture town gas in a single-stage process, where the gas is made straight from coal in one operation, than by a two-stage process, even though the value of the coal per ton is higher than that of the coke, and that this remains until the cost of the coal reaches a figure some 40 to 50 p.ct. above the value of the coke.

Discussion.

The PRESIDENT: I am sure we have all appreciated the very expansive and detailed explanation of the plant and process at Aylesbury, and the subject is now open for discussion.

Dr. R. LESSING: Dr. Travers has described himself as a newcomer to the gas industry, but I should like to point out that, though he has modestly referred to himself in this way, he is rather mistaken, because he is a very distinguished collaborator of the late Sir William Ramsay and has already done a very great deal, if not for the gas industry, at least on the question of our knowledge of gases and particularly on the rare gases in the atmosphere. We must bear this in mind in trying to gauge the importance of the statement that he has made that he is a new-comer to the gas industry. However, he was dealing in those days with incombustible gases; and he has now made his entrance into the field of what we hope to be combustible gases, and from that point of view perhaps he has justly described himself as a new-comer. As I have been engaged on work in the gas industry for some time—perhaps longer than I care to say to-day, I feel gratified at one feature—viz., that Dr. Travers has found that, after all, the pro-

duction of coal gas is not even as simple a process as the isolation of rare gases from the atmosphere; that it is, indeed, a very complicated process into the composition of which a great number of chemical and physical factors enter. There is so much overlapping, and all these factors which make it so very difficult to disentangle in a scientific way—the individual factors which influence the gas industry—have been our difficulty for a long time. I am afraid that even with all the research that we are trying to apply to gas making in its various aspects, we are making only comparatively slow headway. At the same time it is gratifying to see that more and more scientific work of a fundamental character is being applied to elucidate the problem with which you as practical men are concerned. As to the process dealt with in the paper and by Dr. Travers, I should like to point out one feature which apparently has not been taken into consideration, but which I believe Dr. Travers will find plays an important part in his process of recirculation. Dr. Travers claims the advantage for his process mainly from the point of view of thermal conditions, the transmission or transference of heat to the coal by the gas itself, and, on the other hand, the question of the quantities involved in bringing about the chemical reactions of the water gas process on the one side, and the thermal decomposition of the coal on the other. I believe that in recirculation, one important factor is the question of the gaseous atmosphere which is created. Some of you may remember that in a discussion on a very valuable paper by Prof. Cobb some years ago on the use of oxygen in gas-producer practice, I ventured to suggest that quite apart from this ideal object which we hoped might fructify one day, another side must be considered; and that is the provision of hydrogen in the decomposition products of coal. If we can supply an atmosphere sufficiently rich in hydrogen, either in the gas retort or in any producer system in which coal is decomposed, I believe we shall prevent a great deal of undesired decomposition which leads to uncontrolled cracking down, and the entire dissociation of the hydrocarbons or other compounds, with the formation of free carbon. If, on the other hand, a sufficiently hydrogenous atmosphere is obtained, a good deal of this uncontrolled decomposition will be avoided, and hydrogen will be provided in sufficient quantity to take care of the more carbonaceous splitting products of the coal substance. In this way we shall be able to obtain hydrocarbons which tend to preserve their thermal value. I put this view forward even before the time I have already mentioned, as I always felt very strongly about it; and it is for this reason that I welcome this new work of Dr. Travers and his collaborators, because I think it will lead to great advances. It is not only a question of theoretical speculation, for it so happens that in a very practical way this view has already been proved. I believe it is not very well known in this country, but I may tell you of a case which I am sorry to say does not deal with coal but with an analogous substance, oil. The gas-works at San Francisco had been worked for many years past on Californian crude oil for the ordinary water gas process I believe, exclusively for the supply of gas in San Francisco and the neighbourhood. They had been troubled with the asphaltic nature of the oil, which is a crude oil and not a gas oil. They had been troubled with the deposition of excessive amounts of carbon in their generators, and mainly in the carburettor portion. Mr. L. B. Jones, the Manager of the San Francisco Gas Company, some years ago conceived the idea which is practically the same as Dr. Travers' —the recirculating of the gas once made through the whole system. By so doing, he was able to avoid the deposition of free carbon, which, of course, in the case of oil, would be of a very light nature and awkward to remove. He is able to gasify practically the whole of his oil with, possibly, a certain amount of tar formation outside the gas machine, so that, though the conditions differ very considerably—they are much more complicated in the case of coal, partly on account of the solid substance with which we have to deal, the question of ash removal and the like—at the same time, no doubt the problem involved is the same, and the success which has been attained with the process in the case of San Francisco should be a great encouragement to the present workers; and I hope they will achieve the object they have set out to solve.

Mr. GEORGE HELPS: I should like to make a few remarks on this paper, more particularly on the practical side. I do not pretend to be able to follow Dr. Travers through all the actions and reactions that take place in the production of gas. What we are out, as gas makers, to do, is to make, distribute, and sell as much gas as we possibly can for every ton of coal that enters our works. In the paper we have listened to this morning it is clear that the basis of the gas-making proposition is the production of producer gas, water gas, and straight coal gas; and then we have, in addition, some special regenerative effect with the blow. We are all aware that with ordinary carbonizing the best results give us something like 70 therms per ton of coal: water gas 120 therms, and producer gas 200 therms. In the paper, stress has been laid on the necessity and advantages of excluding nitrogen. I think, however, there is no necessity to employ that to the extent it has been employed. Heated nitrogen does work, and very rarely retards other combustibles from doing it. What the production of therms by this process would be if it were continuous and not intermittent, I have not quite gleaned, but I take it that the efficiency is about 55 p.ct.; and this efficiency does not compare with producer-gas practice. Producer gas will give every result which we get from 600 B.Th.U. gas, within limits; and these limits are not met with in our practice. We do not come up against them. What we do come up against is the fact that anybody who distributes a straight coal gas of 500 or 600 B.Th.U. at the usual pressures cannot give his consumers the efficiency to which they are entitled. They do not get it; it is impossible. The gas industry has not yet devised any apparatus whatever that will show instantly, when gas is used, whether it is being used efficiently or not. This is a very simple proposition, and one to which everyone of us will do well to give some attention.

The PRESIDENT: May I suggest that we should be very much obliged if you would confine your remarks to the subject on the paper, which is the plant.

Mr. HELPS: The President has asked me to confine my remarks to the plant, though we have to sell the gas. However, I would like to ask Dr. Travers if he has considered the idea of using pulverized coal in connection with heat conservation in the production of gas. Most of you are aware that pulverized coal now is, so far as fuels are concerned, everyday practice; and coal, when it is pulverized, is as nearly as possible in a fluid state. Therefore it may be used, and will give as good an efficiency, as any gas. I notice that at Aylesbury they are selling coke; and they think they are bound to sell it. I think this is a great mistake. I take it that this plant could have been worked continuously for longer periods, if it had not been for the necessity of producing coke. If they want to produce coke, of course, they can produce it by using pulverized coal instead of coke for heating. This is another aspect which, I think, bears on this paper. You could sell 3 or 4 cwt. of coke more per ton of coal if cheap pulverized coal were used; and this has an application to the plant that has been so excellently described to us. In addition to this, we have to look to the fact that unless we realize that we have to sell gas much more cheaply than we are selling it, we shall find either that we shall get into trouble for several years, or the Government will step in and prohibit the sale of coke. This is my view. Until we get some restrictions with regard to the sale of coke by gas-works, or its probibition altogether, the consumer will not come into his own as regards cheap gas.

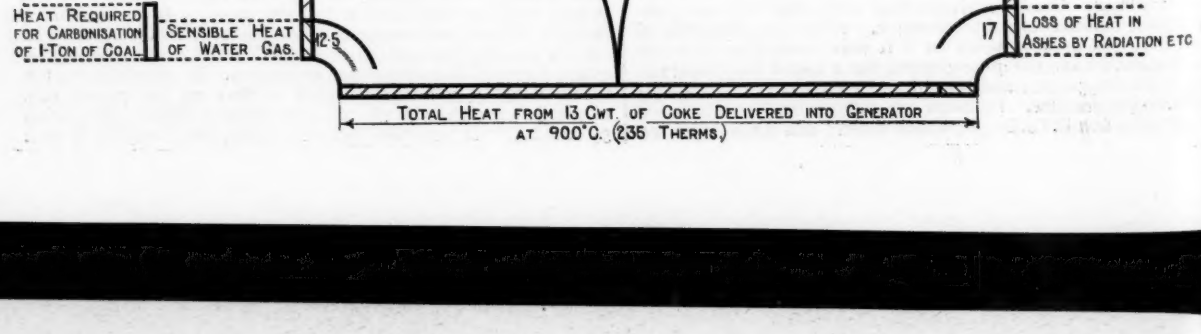
Mr. R. G. SHADBOLT: I should like first of all to congratulate Mr. Lane, the writer of the paper, and Dr. Travers and Mr. Clark, because we have in these contributions a combination of theory and practice which I think, on the face of it, bids fair to assist us very materially in solving a problem that is before those engaged in the industry—the total gasification of coal. I should not have attempted to speak, but for the fact that I have been in practical contact with the total gasification of coal on another plant for the last 4½ years, on the absolute working scale. The plant is nominally the same size as that which has been described to us this morning, but it is a plant which is worked more continuously, and has made in varying proportions from 40 to 90 p.ct. of the gas required in this particular case. Owing to difficulties of obtaining materials for coal-gas plant, and from other considerations, the 4½ years appears now to have passed very quickly. But that period has revealed weaknesses, and has enabled improvements to be effected; and the sum total of them all, to my mind, is that simplification is the keynote of the solution of most of these difficulties. It appears in regard to all inventions and new departures, or nearly so, that we must apparently go through a kind of circumlocutory phase, gradually becoming more and more complicated and complex, and then, from the experience so gained, settle down to a simpler state of affairs and simpler methods of operation. Had this paper been written by one who had been engaged on the total gasification of coal for a period of 4½ years, it could not better describe my own experience in the majority of matters that are mentioned by Mr. Lane—more particularly on such items as the practical absence of naphthalene. In the early stages of total gasification, this was one of the most remarkable facts brought home. Not only was the amount of naphthalene produced practically negligible, but the gas is of such a character as to assist in dissolving the naphthalene—provided it is not in too large quantities—gradually clear of the plant and mains. The method described by Mr. Lane, however, is marred to some extent by its intermittent character, the reason for which he has explained. This undoubtedly accounts for the fact that the gas from the oil is only equal to 0·8 therm per gallon used, whereas we know that 1 therm per gallon is commonly obtained. This must also affect the therm yield from the coal itself to some extent. I do not wish to weary you, and I do not intend to worry you with comparative figures. Mr. Lane makes the point that he is using nothing but coal, and I would like to remind him that this is not the first time that nothing but coal has been successfully used in total gasification. During the 4½ years to which I have referred, I have been working with all coal. Some people, for reasons of their own, make a practice of mixing coke with coal, and some people tell us also that a little coke increases the carbon content, and so improves the water gas portion. This may or may not be correct, but the total gasification of coal is a present-day problem, and it is men such as those who have brought these papers before us whom we require to assist us in solving the practical and theoretical difficulties, and in making it a sound practical and economic proposition. In round figures the result of my 4½ years' experience is that we get 50,000 c.ft. of purified gas per ton of coal; the gross average value being 350 B.Th.U. If you take this as a basis, and compare it with

Mr. Lane's results, and omit all consideration of dry coal and ash—which are matters of calculation—and take it on the basis of the coal you actually have to deal with in every-day practice, then practically Mr. Lane's figures confirm my own experience and *vice versa*, so that the total result is more or less the same. Then, why the difference in the respective plants? When we come to the analysis in Appendix 1, I find, if I compare the 400 B.Th.U. gas with the 350 B.Th.U. gas in the plant I am working, the results are almost identical. If I turn to Appendix 2, and making allowance for the fact that Mr. Lane is working intermittently, my cost is 3·51d. per 1000 c.ft. against 5·85d., taking the same factors into account, or 1d. per therm in my case against his 1·39d. per therm. Therefore, making all allowance for intermittent against continuous working or more regular working, there is very little difference from whichever point of view you look at it. The question then presents itself, What is the special feature, and what is the novelty of this particular plant? There we come on to the circulating portion and the use of the regenerator. Now, in a plant of this kind, which is simply a blue water-gas plant upon which is superimposed a certain amount of carbonizing of coal by which the coke is provided, you have, during the blow period, of necessity a certain amount of heat. What are you going to do with it? One designer of a plant utilizes this heat to heat-up the retort through which the coal passes for the purpose of carbonizing, if he is so producing his coke. Another designer produces oil gas in separate vessels—vertical or horizontal retorts—and he utilizes this heat to raise the steam required. In both these cases, provided the actual final waste heat is a small quantity, you have done exactly what this plant does. In this case, the heat is transferred from the generator by means of gas which is passed backwards. It reminds me of a certain enriching process of many years ago, when I passed a certain quantity of gas back to a certain point, and carried back the hydrocarbon vapours to a certain point. The question is, By making your plant, shall I say, a little more complex than the one which I am more intimately acquainted with, do you gain sufficient to recoup you for the increased expenditure, as there must be some increase in the wear and tear and maintenance? You have thus three different ways of dealing with the waste heat from the blow gases—there may be more—but from the point of view of heat balance, the one which has ultimately the lowest temperature and the smallest degree of heat will be, from that standpoint, of course, the most efficient. As practical gas engineers, I want you to concentrate on these points. Do the additional complexities of plant and working and other things involved compensate for any improvements which are effected? If you take the process with which I have been concerned and compare it with that at Aylesbury, there is very little difference in the over-all efficiency and in the total net result. Consequently, that process which does eventually prove to be the most simple in construction and operation will prove to be the most effective and, I believe, the most economical.

Mr. F. H. ROBINSON (Harrogate): The paper and the other communications to which we have listened this morning are of very great interest to me, inasmuch as I have carried out complete gasification for the last five years at Harrogate. As Mr. Shadbolt has remarked, there is a great similarity in the results obtained from plants of different design and different in principle. In the case of the Aylesbury plant, they rely on the internal heating of the coal; in the Harrogate plant, the principle is entirely different. The coal is carbonized in a horizontal retort with water gas in a generator. The hot water gas then passes through the retorts, and, to a certain extent, internal heating is applied; and then the waste gases from the generator circulate round the retort. Thus you get both external and internal heating. Mr. Lane gets 178·5 therms in the form of gas from the coal as supplied to the plant. We have got 174 therms of 425 B.Th.U. gas, 189 therms of 344 B.Th.U. gas, and 197 therms of 280 B.Th.U. gas. You will observe that the efficiency rises as the quality of the gas is reduced. When working at a balance, gas of about 350 B.Th.U. is produced. By a balance, I mean to say that there is no coke added nor coke removed from the plant. In the efficiency of the one-stage process worked out in the paper, the figure appears to me to be rather low—viz., 55·3 p.ct.—and my feeling is that the figures given are not complete. I think the method of arriving at the heat balance is open to question. In the later figures, tar and coke, although produced, are not credited. In the Harrogate tests we are making 174 therms per ton of coal carbonized of 425 B.Th.U. gas, and we find no less than 30 therms per ton of coal carbonized in the material removed from the generator, which contains 53·8 p.ct. of carbon. It is therefore returned to the boiler for making steam, and taking into account the gas, tar, and this fuel from the generator, the over-all efficiency works out at 66·5 p.ct. It is evident from the figures that the intermittent working has seriously affected the results given, and I think this is also shown at the end of the paper in the labour costs. When the costs given in Appendix 2 are worked out per 1000 c.ft. and per therm, figures of 0·922d. per 1000 c.ft. and 0·22d. per therm are obtained, taking wages at 8s. 4d. per shift. We, however, have an automatic arrangement on our plant whereby the whole of the valve changing is done automatically from a small engine. The plant is worked continuously, and if we take these figures of wages as a basis we obtain 0·58d. per 1000 c.ft. and 0·15d. per therm as labour costs in my case, which is a considerable difference. I think it has been brought out that the cost of operating a complete gasification plant is much lower than that of other systems, inasmuch as there is no quenching of the coke; there is no taking away of the coke from the retort bench and bringing it back to the water-gas plant, and you are able to control the quality. If the gas is getting poor, due to the unsealing of a bed or from a similar cause, it is an easy matter to shut-off the steam to the plant and close it down, and allow the plant to work as a separate coal-gas producer until the quality recovers. It is a thing we often do, and that is a very useful point in connection with a complete gasification plant.

Mr. W. M. CARR (Stretford): There is one point I should like to ask the reader of the paper and his collaborators. [Mr. Carr then asked for the information given in the additional table after Appendix 2, which was printed apart from the paper at the time of its distribution at the meeting, and was brought to his notice at the time he made his point.] There is one other point, and that is that great claims are made for this process on account of the transference of heat direct from the gases which are passed through. In fact, the whole basis of the plant is the direct transference of heat, and not carbonization by conduction. I have recently had to conduct some experiments on a plant not installed at a gas-works which you, Mr. President, referred to in your address yesterday. I think you had the same plant in mind. In that, there is a retort superimposed upon the top of the producer, and the fuel is moved through the retort by mechanical means. I am not in a position to put forward any figures, although I shall be able to do so at a later date; but the extraordinary thing has been the great degree of carbonization at low temperature that can be obtained by direct transference, and especially if mechanical means are employed for turning over the fuel, so that the fuel which in ordinary carbonization apparently forms a skin, on the outside, of partially carbonized material—which is not a good conductor of heat—does not do this. With this mechanical means, however, the amount of heat transference which has been obtained with this retort is very great indeed—so much so, that carbonization has been practically complete with as low a temperature as 550° Fahr. One can readily appreciate the efficiency which has been obtained on this plant at Aylesbury, which, I am sure, must appeal to everybody as being a distinct advance on anything that has been done before, inasmuch as the principle of direct transference of heat, and not conduction, has been developed to a greater degree.

Mr. LANE, replying to the discussion, said: Mr. Helps' remarks apply to Dr. Travers in particular, and not as far as I am concerned as a gas maker. Mr. Shadbolt referred to the 0·8 therm per gallon of oil. There is no doubt that we are short in our


TOTAL HEAT OF BLOW GAS.
90
LATENT HEAT OF WATER GAS.
115·5
HEAT REQUIRED FOR CARBONISATION OF 1-TON OF COAL
SENSIBLE HEAT OF WATER GAS.
12·5
17
LOSS OF HEAT IN ASHES BY RADIATION ETC
TOTAL HEAT FROM 13 CWT. OF COKE DELIVERED INTO GENERATOR AT 900°C. (235 THERMS.)

efficiency for cracking of oil with this plant; but, as I have mentioned before, consideration has been given to this, as the result of experiment, which will enable the plant to be altered in the future. The expense of maintaining the plant has been mentioned, but I might say that up to the present the actual expenditure has been £25, and that was for relining a generator once since we have been running it. Mr. Robinson referred to certain calorific values, but that is on a totally different plant from what we are running at Aylesbury; and really, although these figures are very useful for reference and for comparison, I do not quite see that they apply to us in any sense. With regard to Mr. Carr, I got out Appendix 2 of the paper to begin with, but several people rang me up and suggested it would be better to include coal. I had specially left it out so that managers might fill in any price of coal which they were paying, but I have since worked out the separate table showing coal prices from 20s. to 40s. per ton. My Chairman would have liked to be here to support me at the meeting, but he wishes me to say that any member of the Institution who would care to come and see this plant will be welcomed by the Chairman and the Company. We shall be very pleased for anyone who wishes to do so to visit the plant at Aylesbury.

The PRESIDENT: I am sure that the invitation of the Chairman and Directors of the Aylesbury Gas Company, supported as it is by their Engineer, will be welcomed by the members of the Institution. I personally have visited the works, and am very pleased to acknowledge the courtesy with which facilities were extended to me for an investigation of the plant.

Dr. TRAVERS: I also should like to acknowledge the assistance of the staff and management of the Aylesbury Gas Company. With reference to the discussion, Dr. Lessing has referred to Mr. Jones' work. As a matter of fact, I had a note in the paper originally with regard to this, acknowledging Mr. Jones' work in the matter, but I cut it out because I thought Prof. Cobb's work illustrated the point sufficiently. As to Mr. Carr's remark regarding the direct transfer of heat, there was a reference made during a discussion on fuel, when representatives of the Fuel Board took part, as to the effect of steam in facilitating the distillation of coal by its chemical action. I read that remark somewhere, but I have been unable to trace the reference, and if anyone can put me on the track of it I shall be very much obliged.

Mr. F. W. CLARK: I want to refer to Mr. Helps' remarks. I expected to hear from him, and am very pleased he spoke; but I really thought I had got over the difficulty, because in the paper I refer to the regulations and restrictions under which you are working, and I might almost have written "Mr. Helps" instead of that word "restriction." We are extremely glad to hear what Mr. Carr had to say as to his work on the direct application of heat; it is most encouraging to have such remarks, because, as you will have gathered, we are working on the direct application of heat. Mr. Robinson is to be congratulated on his figures. We have not had time to get down to it, but we know that he is obtaining 197 therms of 280 B.Th.U. gas from a ton, and that is really very good, because if you take water gas and get 60,000 c.ft. out of a ton, you are still a long way below 197 therms. We are going to give very great attention to this figure. We are very much encouraged by Mr. Shadbolt's remarks, and by the fact that we are really getting results which are good enough to be called equal to others. I do not think there is anything else, except one thing which Dr. Travers has referred to, and that is the many processes which you have to work if you are going to get gas of the calorific value to which you are of necessity restricted. In this process we have three things—a producer, a generator, and a carburettor—and through the regenerator we have to get a reverse flow to secure efficiency. The heating gas must go through in one direction, the gases to be heated go through in another direction, and to get efficiency in the carburettor you have to have exactly the reverse thing. You have to have the heating gases entering in the same direction as the gases to be heated, so that you have quite a lot of things to do. I am just mentioning this because it was suggested that the plant should be a little simpler. But although the gases pass in the manner I have pointed out, we do all this without the use of any hot valve; the gas is controlled by a small valve on the cold gas.

INSTITUTION GAS RESEARCH FELLOWSHIP, 1924.

THE GASIFICATION OF COKE IN STEAM, WITH SPECIAL REFERENCE TO RATES OF GASIFICATION AND THE COMPOSITION OF THE GAS.

By S. PEXTON, Ph.D., M.Sc. (Institution Gas Research Fellow), and J. W. COBB, C.B.E., B.Sc. (Livesey Professor in the University of Leeds).

INTRODUCTION AND SUMMARY.

In the work previously carried out by us on the gasification of coke in steam, the results of which were reported last year, special attention was paid to the factors determining the production of ammonia and sulphuretted hydrogen. Rates of gasification with different cokes at several temperatures were also determined, but the composition of the gas produced was not studied in any detail. It was, however, pointed out that the proportion of gasified nitrogen recovered as ammonia was dependent not only on the temperature of gasification, but on the concentration of undecomposed steam in the exit gases. It has been considered advisable to investigate further the composition of the gas and the amount of undecomposed steam as varying with temperature, the velocity of gas stream, and the nature of the coke used. If our results are examined and considered, the following points emerge.

With a high temperature, such as 1000° C., using an ordinary coke in powder or very small pieces (as in our laboratory experiments) closely packed so that good contact between the steam, gases, and coke is ensured, the gaseous products of the reaction between the carbon and steam assume very rapidly an equilibrium composition in the reversible reaction $CO + H_2O \rightleftarrows CO_2 + H_2$, corresponding with 1000° C., *i.e.*, the ratio $\frac{[CO]\ [H_2O]}{[CO_2]\ [H_2]}$ becomes approximately 1·6 (see Tables III. and III.a below, experiments 10–21).

This does not mean, however, that good water gas, low in CO_2 and H_2O, has necessarily been made, since that equilibrium can be attained with high CO_2, when the undecomposed steam is also high (Tables III. and III.a, experiments 17–21).

The key to the interpretation of the results obtained in our study and in the large-scale experiments of the Gas Investigation Committee, to which reference is made below, is to be found in the action of the hot coke surface in speeding up the interaction of the products of gasification in close contact with it. As a consequence, the equilibrium value for the ratio $\frac{[CO]\ [H_2O]}{[CO_2]\ [H_2]}$ is rapidly attained in the surface films of gas next the coke very much more rapidly than in the gas outside the films in the free space between pieces of coke. In our laboratory experiments with powdered coke at 1000° C., when the rate of steam supply was low, the large ratio of coke surface to volume, the smallness of the interstices, the relatively small quantity of steam, and considerable time of contact combined to secure almost complete decomposition of steam, the attainment of the equilibrium value (1·6) for the ratio $\frac{[CO]\ [H_2O]}{[CO_2]\ [H_2]}$, and an equilibrium composition very low in CO_2 and H_2O—a good water gas. The resultant composition in that case corresponds approximately with the primary equation for high-temperature reaction, $C + H_2O \rightarrow CO + H_2$ (see Tables III. and III.a below, experiments 10-21). When the steam was supplied more rapidly, the gas made on the surface of the coke would again be low in CO_2 and H_2O, but would then mix with the undecomposed steam round it. In this bed of finely-divided coke, with its minute interstices and large surface per unit volume, so much gaseous interaction between the steam and gas in surface films would then result that, before the gas stream escaped, the equilibrium ratio would be attained as before, but the corresponding equilibrium composition would be quite different, with more CO_2 and H_2O (Table III. and III.a, experiments 17–21). With a still higher rate of steam supply, some of the steam would not only escape decomposition, but would not have the opportunity of completing its interaction in the

TABLE I.—(*Bunte and Harries*).

Gas Velocity, Litres/Sec.	Temp. °C.	Percentage Composition of Gas Leaving Heated Carbon.				$\frac{[CO]\,[H_2O]}{[CO]\,[H_2]}$.	$\frac{[CO]\,[H_2O]^*}{[CO_2]\,[H_2]}$ read from Graph of Hahn's Experimental Values.	$\frac{CO^*}{CO_2}$.
		H_2.	CO.	CO_2.	H_2O.			
0·9	674	8·41	0·63	3·84	87·12	1·70	0·51	0·16
1·8	758	22·28	2·67	9·23	65·82	0·85	0·76	0·29
3·66	838	28·68	6·04	11·29	54·09	1·01	1·03	0·54
3·28	838	32·77	7·96	12·11	47·15	0·94	1·03	0·66
5·3	861	36·48	11·01	13·33	39·18	0·89	1·11	0·82
6·3	954	44·43	32·70	5·66	17·21	2·25	1·45	5·8
6·15	1010	47·30	48·20	1·45	3·02	2·12	1·65	33·1
9·8	1060	48·84	46·31	1·25	3 68	2·78	1·81	37·1
11·3	1125	50·73	48·34	0·60	0·33	0·48	1·99	80

* These columns have been added by us for purposes of comparison.

gas stream, so that the ratio $\frac{[CO]\,[H_2O]}{[CO_2]\,[H_2]}$ would be higher than that of the equilibrium value, and the gas would be high in CO_2 and particularly in H_2O (Tables III. and III.a, experiments 22–23). Another condition obtains in large-scale work such as that undertaken by the Gas Investigation Committee on a water-gas plant. There the steam passed through several feet of lump coke instead of a few inches of coke powder as in our laboratory experiments. As before, good water gas, low in CO_2 and H_2O, would be made on the surface of the coke, and it would mix more or less with the undecomposed steam in the interstices, but these would be so large that surface action on the mixture, and consequent change in composition, would be very small. Thus, the gas obtained finally would be the same in composition as if a portion of the steam had been allowed to act at 1000° C. with ample contact with carbon, and another portion had been by-passed. The undecomposed steam and the ratio $\frac{[CO]\,[H_2O]}{[CO_2]\,[H_2]}$ were therefore high, the latter far above the equilibrium value, but the CO was high and the CO_2 low—a good water gas mixed with undecomposed steam (Table VII.). Close approach to equilibrium in the gas stream would have meant the production of a worse water gas, richer in CO_2. There is, then, a practical advantage in the non-attainment of equilibrium, although it involves a thermal loss in the sensible and latent heat of the undecomposed steam. Another way of expressing the difference between the large-scale results and those obtained with finely-divided coke in the laboratory would be to say that, whereas in the former case the steam underwent decomposition by direct interaction with solid carbon, or escaped decomposition altogether, in the latter case it was liable to undergo extensive decomposition by gaseous interaction in the gas films next the carbon, according to the equation $CO + H_2O \rightarrow CO_2 + H_2$.

It has been indicated in our previous work that hard coke gasified much more slowly than soft coke, and that was confirmed. The stage was much sooner reached with a hard coke at which, as the steam supply was increased, the ratio $\frac{[CO]\,[H_2O]}{[CO_2]\,[H_2]}$ passed well above that of the equilibrium value and undecomposed steam escaped ir quantity. This was very noticeable with a sample prepared in the laboratory at the high temperature of 1270° C.

An interesting phenomenon was noticed in the series of experiments at 1000° C. (Table III.). In that table the percentage of steam undecomposed rises gradually with the rate of steam supply and a corresponding alteration occurs in the gas composition. Comparison of the results obtained when approximately the same amount of steam was supplied per hour, in one experiment with a low, and in another with a high dilution of inert nitrogen, will show that very nearly the same rate of gasification, decomposition of steam, and composition of water-gas resulted (*e.g.*, experiments 10 and 11, 20, and 21). The time of contact, however, must have been very much lower in the mixture heavily diluted with nitrogen, and the concentration of steam present in the tube at any time much smaller. The gas stream must, on the other hand, have been moving much more rapidly. Apparently this rapid motion with its turbulence, and its thinning or penetrating effect upon the gas film covering the coke (through which film gasification must be effected) compensated for the diminished time of contact, so that in the end the rate of gasification was the same for the same steam supply although the time of contact was so much smaller.

A thermal analogy to this seemingly strange quantitative compensation was discussed by Osborne Reynolds in 1874, who deduced that in a boiler tube "for considerable velocities the gas should emerge from the tube at a nearly constant temperature whatever may be its velocity," while in 1897 Stanton described how he had forced water at different temperatures through two concentric pipes and found that at quite different speeds the change of temperature produced in a given length of pipe was pretty much the same (see Perry's Steam Engine, pp. 596, 586). In both these cases the influence of the stationary film next to the solid was all-important.

The Work of Others.—In the work previously reported by us [1] no attempt was made to determine directly the proportion of steam decomposed in any series of experiments. It was, however, clear from evidence presented that cokes prepared under different conditions from one and the same coal varied in the extent to which, at any temperature, they decomposed steam, the same time of contact between the steam and coke and the same rate of steam supply being allowed in each case. The desirability of more precise information on this point led us to continue our experiments in such a way as to allow the proportion of steam decomposed and the composition of water gas produced to be determined. The conditions of such experiments may, or may not, allow equilibrium to be reached in the reaction products, and the results previously obtained by different investigators at times are difficult to correlate.

Bunte and Harries [2] passed steam over carbon (charcoal or coke) at various temperatures, and analyzed the gases produced. The wet-gas compositions are given in Table I. and represented graphically in fig. 1. Comparison with the experimental results of Hahn [3] obtained by an entirely different method would suggest that equilibrium in the reversible reaction $CO + H_2O \rightleftarrows CO_2 + H_2$ had been, roughly speaking, attained excepting at dull redness (674° C.), the expression $\frac{[CO]\,[H_2O]}{[CO_2]\,[H_2]}$ reaching a constant value at each temperature, increasing with temperature. The wet gas leaving the heated carbon contained as much as 87 p.ct. of steam at the lowest temperature, but only a fraction of 1 p.ct. at 1010° C. Although the results of these

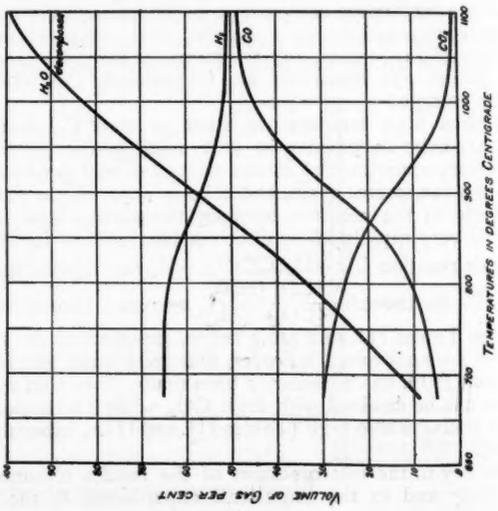


Fig. 1.

Clement, Adams, and Haskins' Results.

Variety of Carbon.	Temp. °C.	Time of Contact. Secs.	Composition of Wet Gas. P.Ct. by Volume.*				$CO + 2CO_2$.	$\frac{[CO]\ [H_2O]}{[H_2]\ [CO_2]}$	$\frac{CO}{CO_2}$	P.Ct. of Steam Decomposed.
			H_2O.	CO_2.	CO.	H_2.				
Coke	800	1·02	99·1	0·06	0·40	0·49	0·52	1050	6·7	0·5
	900	8·35	75·4	2·75	8·51	12·78	14·01	18·2	3·1	14·5
		2·96	89·5	0·75	4·36	5·22	5·86	100·0	5·8	5·5
		1·47	89·5	0·91	4·16	5·25	5·98	78·0	4·6	5·5
	1000	6·98	69·8	4·38	9·16	15·80	17·92	9·2	4·8	18·5
		3·42	78·4	2·40	7·53	11·28	12·33	21·8	3·1	13·6
		1·02	88·7	0·91	4·48	5·71	6·30	76·5	4·9	10·5
	1100	7·97	34·9	9·8	18 8	35·6	38·4	1 88	1·9	50·0
		1·97	67·6	4·4	9·9	17·6	18·7	8·65	2·25	23·4
		1·03	76·8	3·16	7·22	12·4	13·54	14·4	2·28	16·1
	1200	11·05	5·0	0·3	51·3	42·5	51·9	2 0	171·0	89·5
		2·13	52·3	0·4	24·2	22·3	25·0	144·0	60·5	30·0
Charcoal	1100	6·92	0·9	0·0	50·5	47·3	50·5	..	..	98·0
		1·77	20 8	0·4	39 6	39·3	40·4	52·6	99·0	93·0

* Where the wet gas compositions do not total to 100 p.ct. the discrepancy is claimed to be due to the gas having become contaminated with air after leaving the reaction tube.

experiments are widely quoted, there seems to be very little exact and detailed information published as to how they were obtained.

Farup [4] passed steam and nitrogen over a rod of electrode carbon at temperatures between 800° and 900° C., allowing the long time of contact with the carbon of 5 minutes. Although the gas velocity through the reaction zone was as low as 2·3 c.c. (at 0° C. and 760 mm.) per minute, the change in concentration of water vapour between inlet and outlet gas was never greater than from 44·3 to 35·9 p.ct., which illustrates the extreme sluggishness of reaction between steam and a particularly hard variety of carbon at temperatures below 900° C.

Clement, Adams, and Haskins [5] passed steam over carbon (coke and wood charcoal) at various temperatures and with various times of contact.

The following table has been constructed from their results, the columns ($CO + 2CO_2$), and $\frac{[CO]\ [H_2O]}{[CO_2]\ [H_2]}$ being added by us for purposes of comparison. Note that, if the only reaction occurring is the decomposition of steam by carbon, the volume of hydrogen produced must be that of ($CO + 2CO_2$), the oxygen of the steam gasifying the carbon.

In contrast with the results of Bunte and Harries, the gas compositions given here show very marked departures from those of equilibrium in the reaction $H_2O + CO \rightleftarrows CO_2 + H_2$. The sluggishness of interaction between the coke and the steam is a marked feature of the results, and it is regrettable that no description of the coke was recorded.

Haslam, Hitchcock, and Rudow [6] have recently examined the effect of steaming coke and arc carbon at various temperatures

(*a*) under a pressure of half an atmosphere, and

(*b*) under a pressure of one-and-a-half atmospheres.

The threefold increase of pressure produced little change in gas composition, but resulted in an increased rate of gas production. It would appear from our own results reported in this paper, that the increased rate of gas production in their experiments was due, not so much to any increase in pressure as to the increased quantity of steam passing over the coke in unit time in the experiments of series (*b*). The gas compositions approached equilibrium for the reaction $CO + H_2O \rightleftarrows C_2O + H_2$, so resembling those of Bunte and Harries.

Our own experiments were made by gasifying in steam, usually at 1000° C., but for some purposes at another temperature, cokes prepared in different ways from one kind of coal.

Experimental.

The types of coke examined were, as in our previous investigation, prepared from Blackwell (Derbyshire) coal of the following proximate composition, although the same sample of coal was not used.

Proximate Analysis of Coal (air-dried).

	P.Ct.
Loss at 105° C.	6·5
Volatile matter	33·9
Ash	5·8
Fixed carbon	53·8
	100·0

Preparation of Cokes.

(*a*) *Medium Temperature* (900° *C.*) *Coke.*

A sample of finely-crushed coal was charged into fireclay crucibles. The crucible lids, through which a hole for gas escape was drilled, were cemented in position using fireclay slip. The crucibles were heated in a surface-combustion gas-fired furnace supplied by British Furnaces, Ltd., temperatures being controlled with the aid of an optical pyrometer sighted on the outside of one of the crucibles. After carbonizing for four hours at the maximum temperature of 900° C., seven hours altogether, all the crucibles were withdrawn from the furnace and allowed to cool in air. The coke was crushed, and the portions passing a sieve of $\frac{1}{6}$ in. aperture, but remaining on a sieve of $\frac{1}{8}$ in. aperture, and passing a sieve of $\frac{1}{8}$ in. aperture, but remaining on one of $\frac{1}{10}$ in. aperture, were retained. As gasified, each coke sample consisted of four parts of material $\frac{1}{6}$ in.—$\frac{1}{8}$ in., and 1 part of material $\frac{1}{8}$ in.—$\frac{1}{1}$ in.

(*b*) *High-Temperature* (1270° *C.*) *Coke.*

This was prepared in the way described above, but at the higher temperature. The following coke yields were obtained in the laboratory:

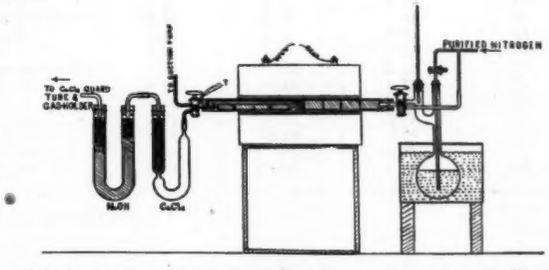
Medium-temperature (900° C.) coke	65 p.ct.
High-temperature (1270° C.) coke	62 p.ct.

(*c*) *Metallurgical Coke.*

A sample of bye-product coke (the one used by us previously) prepared from the same class of coal at Blackwell coke-ovens was also examined. Samples of this coke as gasified in our experiments were made up as follows:

3 parts of material	$\frac{1}{4}$ in. — $\frac{1}{2}$ in.
1 part of material	$\frac{1}{2}$ in. — $\frac{1}{4}$ in.
1 part of material	$\frac{1}{4}$ in. — $\frac{1}{10}$ in.

The apparatus (see illustration) and method of experiment were substantially the same as previously described by us.



Purified nitrogen saturated with steam at some observed temperature was passed over coke maintained at a constant temperature. The water-gas-nitrogen-steam mixture from the reaction was led through weighed calcium chloride and caustic soda tubes into a gasholder. The undecomposed steam and carbon dioxide were estimated gravimetrically; the carbon monoxide and hydrogen being determined volumetrically from corrected volume measurements of the gas collected and the analyses made with the Bone and Wheeler apparatus. The coke was packed between silica blocks which held it in position, and by reducing the free space in the ends of the tube shortened the time of escape of the

TABLE II.—*Bye-Product Coke Gasified at* 900° *C.*

No. of Experiment.	Duration of Steaming (Hours).	Gasification Range.	Volume of Wet-Gas Constituents leaving Tube (Litres per hour at N.T.P.) from 10 g. of Coke.							$CO + 2CO_2$.	$\frac{[CO]\,[H_2O]}{[CO_2]\,[H_2]}$	$\frac{CO}{CO_2}$	P.Ct. of Steam Decomposed.
			CO.	CO_2.	$CO + CO_2$.	H_2.	H_2O.	$H_2 + H_2O$.	N_2.				
		P.Ct.											
1	0– 2½	0–15	0·4	0·58	0·98	1·44	3·9	5·34	4·4	1·56	1·87	0·7	27
2	0– 5½	0–33	0·4	0·54	0·94	1·44	4·2	5·64	4·4	1·48	2·16	0·75	25·6
3 (a)	0– 2½	0–14	0·42	0·57	0·99	1·44	4·2	5·64	4·2	1·56	2·1	0·75	25·6
3 (b)	2½–10	14–56	0·46	0·52	0·98	1·43	4·0	5·43	4·3	1·5	2·47	0·9	26·4
4	10–15	56–73	0·34	0·26	0·60	0·82	4·8	5·6	4·5	0·86	7·8	1·3	14·6
5	29 mins.	..	0·50	0·77	1·27	1·94	7·34	9·28	6·7	2·04	2·54	0·65	21
6	60 ,,	..	0·29	0·38	0·67	1·03	1·96	2·99	2·2	1·05	1·45	0·75	34·5
7	..	..	0·37	0·54	0·91	1·34	4·43	5·77	6·0	1·45	2·26	0·7	23·1
8	..	..	0·41	0·50	0·91	1·37	4·03	5·4	4·8	1·41	2·41	0·8	25·4
	..	..	0·32	0·47	0·79	1·21	2·94	4·15	3·4	1·26	1·65	0·7	29·2

TABLE IIA.

No. of Experiment.	Dry Gas Compositions. Percentages by Volume.			Volume of Dry Water Gas Produced Litres/Hour at N.T.P.	Time of Contact of Gases with Coke. (Secs.)*		Rate of Steam Supply. Litres per Hour at N.T.P.
	CO.	CO_2.	H_2.		t_1.	t_2.	
1	16·5	24	59·5	2·42	1·07	0·97	5·34
4	15·5	24	60·5	3·21	0·65	0·60	9·28
5	17	22·3	60·7	1·7	2·15	1·78	2·99

* The time of contact t_1 was calculated assuming the volume to be that of the entering gas (steam and nitrogen), while t_2 was calculated assuming the volume to be that of the gas leaving (water gas, steam, and nitrogen). It makes little practical difference which of the two is taken.

TABLE III.—*Gasification of Bye-Product Coke at* 1000° *C.*

No. of Experiment.	Volumes of Wet Gas Constituents Leaving Tube (Litres per Hour at N.T.P.) from 10 g. of Coke.							$CO + 2CO_2$	$\frac{[CO]\,[H_2O]}{[CO_2]\,[H_2]}$	$\frac{CO}{CO_2}$	P Ct. of Steam Decomposed.
	CO	CO_2.	$CO + CO_2$.*	H_2.	H_2O.	$H_2 + H_2O$.†	N_2.				
9	1·06	0·03	1·09	1·12	0·08	1·2	0·9	1·12	2·54‡	35	92·5
10	2·2	0·1	2·3	2·22	0·16	2·4	13·4	2·4	1·59	22	92·5
11	2·25	0·18	2·43	2·56	0·33	2·9	2·0	2·61	1·61	12·5	88
12	2·35	0·20	2·55	2·7	0·4	3·1	1·5	2·75	1·65	11·7	87
13	2·62	0·35	2·97	3·38	0·67	4·05	12·1	3·32	1·48	7·5	83·5
14	3·2	0·5	3·7	4·13	1·1	5·2	3·6	4·2	1·7	6·4	79·5
15	3·3	0·6	3·9	4·1	1·3	5·4	1·0	4·5	1·78	5·5	76·0
16	3·7	0·76	4·46	5·2	1·6	6·8	11·2	5·22	1·5	4·9	76·5
17	3·7	1·05	4·75	5·6	2·5	8·1	12·1	5·7	1·59	3·5	68·5
18	3·52	1·32	4·84	6·1	3·6	9·7	3·9	6·16	1·58	2·7	63
19	3·5	1·4	4·9	6·3	3·9	10·2	7·6	6·3	1·54	2·5	62
20	4·1	2·0	6·1	8·1	6·9	15·0	3·2	8·1	1·74	2·0	54
21	4·2	2·2	6·4	8·4	7·8	16·2	11·4	8·6	1·77	1·9	53
22	5·4	3·4	8·8	12·3	16·5	28·8	7·3	12·2	2·13	1·6	43
23	5·45	3·6	9·05	12·5	20·4	32·9	11·0	12·65	2·48	1·5	38

* Indicating rate of gasification of carbon.
† Indicating rate of steam supply.
‡ This figure is unreliable because of the difficulty experienced in measuring the small quantities of H_2O and CO_2 involved.

TABLE III.A.

No. of Experiment.	Dry Gas Compositions. Percentages by Volume.			Volume of Dry Water Gas Produced. Litres per Hour at N.T.P.	Rate of Steam Supply. Litres per Hour at N.T.P.	Time of Contact of Gases with Coke (Secs).		
	CO.	CO_2.	H_2.			t_1.*	t_2.*	Average.
9	48	1·3	50·7	2·21	1·2	4·6	3·0	3·8
10	48·7	2·2	49·1	4·52	2·4	0·61	0·53	0·58
11	45·2	3·6	51·2	4·99	2·9	1·97	1·33	1·65
12	44·8	3·8	51·4	5·25	3·1	2·1	1·35	1·72
13	41·2	5·5	53·3	6·35	4·05	0·6	0·5	0·55
14	41	6·4	52·6	7·83	5·2	1·1	0·77	0·93
15	41·2	7·5	51·3	8·0	5·4	1·78	1·03	1·40
16	38·3	7·9	53·8	9·66	6·8	0·53	0·43	0·48
17	35·7	10·2	54·1	10·35	8·1	0·48	0·39	0·43
18	32·1	12·1	55·8	10·94	9·7	0·71	0·52	0·62
19	31·3	12·5	56·2	11·2	10·2	0·55	0·42	0·48
20	28·9	14·1	57·0	14·2	15·0	0·53	0·40	0·46
21	28·4	14·9	56·7	14·8	16·2	0·35	0·28	0·32
22	25·6	16·1	58·3	21·1	28·8	0·27	0·21	0·24
23	25·3	16·7	58·0	21·55	32·9	0·22	0·19	0·20

* t_1 from gas entering, t_2 from gas leaving, coke column.

gaseous products after traversing the coke column. At the commencement of each experiment, air was removed from the tube by evacuation and replaced by nitrogen.

In our previous work under similar conditions, it was shown that the weight of coke gasified during unit time was approximately constant over the period required for gasification of the first 50 p.ct. of the coke. Experiments described below (unless otherwise stated) have been confined within this period in order to avoid the irregularities which reveal themselves in the more advanced stages of gasification.

Approximately 10 grammes of coke were used in all experiments. All gas volumes are corrected to N.T.P. and calculated as hourly rates. In calculation of the volume of carbon dioxide in the products of gasification, allowance has been made for the H_2S simultaneously absorbed by the caustic soda, on the basis of work previously presented.

GASIFICATION OF BYE-PRODUCT COKE AT 900° C.

The results of gasifying bye-product coke at 900° C. are given in Table II., and represented graphically in fig. 2.

Experiments 4 and 5, and 6, 7, and 8 were performed on the same charges of coke respectively, a sufficient time

interval being allowed between one experiment and the next for constancy in conditions of reaction to be attained.

The saturation temperatures in these experiments, and therefore the relative volumes of nitrogen and steam, were maintained approximately constant, but in one experiment, No. 4, the rate of steam supply was approximately doubled, and in another experiment, No. 5, approximately halved, with corresponding diminution and increase in the times of contact.

Hahn's equilibrium value for the expression $\frac{[CO]\ [H_2O]}{[CO_2]\ [H_2]}$ at 900° C., as read from his graph of experimental results, is 1·25.

In drawing up the table of results, the combined values "$CO + CO_2$" and "$H_2 + H_2O$" have been included. Each "$CO + CO_2$" value is a measure of the rate at which the carbon gasified, while the "$H_2 + H_2O$" value represents the rate of steam supply to the coke column.

The experiment in which the ratio $\frac{[CO]\ [H_2O]}{[CO_2]\ [H_2]}$ approached nearest to the equilibrium figure was experiment 5, with the longest time of contact, and that in which the highest value, furthest from the equilibrium value, was reached was experiment 4, with the shortest time of contact—this, with the exception of experiment 3b, which requires a special explanation given below. The percentage of steam decomposed is also seen to have attained its highest value in experiment 5 and its lowest in experiment 4. It is noticeable that the dry-gas compositions given in Table II.a show little change with variation in steam velocity, and represent very bad water gas with high CO_2.

The exceptional results from experiment 3b are typical of others obtained when a very large proportion of the carbon in the coke had been gasified previously, and contact between steam and carbon thereby rendered unsatisfactory.

GASIFICATION OF BYE-PRODUCT COKE AT 1000° C.

The results of gasifying bye-product coke at 1000° C. are given in Tables III. and III.a, and graphically represented in fig. 3.

Hahn's equilibrium value for the expression $\frac{[CO]\ [H_2O]}{[CO_2]\ [H_2]}$ at 1000° C. as read from his graph of experimental results was 1·62.

The influence of the higher temperature of gasification is plainly seen in that the wet-gas compositions at 1000° C., even with higher steam velocities, represented approximately the attainment of equilibrium conditions in the gaseous reaction products.

From the following comparison of experiment 10 with experiment 11, and experiment 17 with experiments 18 and 19, it would appear that the hourly rate at which the coke gasified was dependent upon the rate of steam supply and independent of the partial pressure of the steam entering or leaving the system.

This fact greatly simplifies the comparison for any purpose of the results of this and our previous investigation in removing the apprehension that the diluent nitrogen would lessen the amount of action between steam and carbon, and so reduce the steam decomposition.

No. of Experiment.	Partial Pressure of Steam in Nitrogen-Steam Mixture Entering (mm. Mercury).	Partial Pressure of Steam in Nitrogen-Water Gas-Steam Mixture Leaving (mm. Mercury).	Volume of N_2 Passed. Litres per Hour at N.T.P.	Rate of Steam Supply. Litres per Hour at N.T.P.	CO + CO_2 Formed. Litres per Hour.
10	115	67	13·4	2·4	2·3
11	450	45	2	2·9	2·43
17	400	105	12·1	8·2	4·75
18	710	195	3·9	9·7	4·84
19	435	173	7·6	10·2	4·9

From a comparison of the "$CO + CO_2$" curves of figs. 2 and 3, it will be seen that the hourly rate of gasification of the bye-product oven coke at 1000° C. was four times that of the same coke at 900° C.

GASIFICATION OF HIGH-TEMPERATURE (1270° C.) COKE AT 1000° C.

The gasification at 1000° C. of this coke prepared in the laboratory at the high temperature of 1270° C. yielded the results given in Tables IV. and IV.a, and represented graphically in fig. 4.

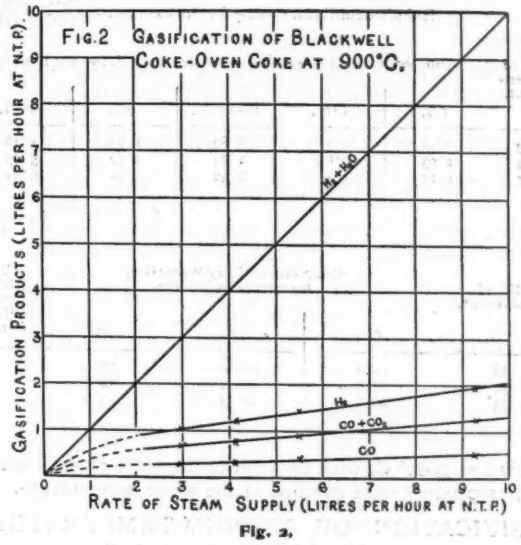


FIG.2 GASIFICATION OF BLACKWELL COKE-OVEN COKE AT 900°C.
GASIFICATION PRODUCTS (LITRES PER HOUR AT N.T.P.)
RATE OF STEAM SUPPLY (LITRES PER HOUR AT N.T.P.)
H₂+H₂O
H₂
CO+CO₂
CO
0 1 2 3 4 5 6 7 8 9 10

Fig. 2.

The gas compositions for times of contact less that 0·5 sec. showed much greater departures from the water-gas equilibrium $CO + H_2O \rightleftarrows CO_2 + H_2$ than was the case in similar experiments with bye-product coke. It is thus evident that differently prepared cokes from the same coal do not react at the same rate with steam, or accelerate to the same extent gas reactions proceeding at their surface. The high-temperature (1270° C.) laboratory-prepared coke

TABLE IV.—*Gasification of High-Temperature* (1270° C.) *Coke at* 1000° C.

No. of Experiment.	Volume of Wet Gas Constituent leaving Tube (Litres per Hour at N.T.P.) per 10 g. of Coke.							$CO + 2CO_2$.	$\frac{[CO]\ [H_2O]}{[CO_2]\ [H_2]}$	$\frac{CO}{CO_2}$.	P.Ct. of Steam Decomposed
	CO.	CO_2.	$CO + CO_2$	H_2.	H_2O.	$H_2 + H_2O$.	N_2.				
24	1·74	0·55	2·29	2·78	1·4	4·2	3·75	2·74	1·59	3·2	66·5
25	2·0	0·74	2·74	3·5	2·8	6·3	3·5	3·48	2·14	2·7	55·5
26	2·45	0·96	3·41	4·5	4·0	9·5	9·3	4·37	2·3	2·6	47·5
27	2·95	1·2	4·15	5·4	10·1	15·5	5·1	5·35	4·6	2·5	34·8
28	3·16	1·1	4·26	5·65	14·8	20·5	11·7	5·26	7·5	2·9	27·5
29	2·88	1·15	4·03	5·1	35·3	40·4	9·5	5·18	13·3	2·5	12·6

TABLE IVa.

No. of Experiment.	Dry Gas Compositions. Percentages by Volume.			Volume of Dry Water Gas Produced. Litres/Hr. at N.T.P.	Rate of Steam Supply. Litres/Hr. at N.T.P.	Time of Contact of Gases with Coke. (Secs.)		
	CO.	CO_2.	H_2.			t_1.	t_2.	Average.
24	34·4	10·8	54·8	5·07	4·2	1·21	0·94	1·07
25	32·1	11·7	56·2	6·24	6·3	0·98	0·77	0·87
26	31·0	12·3	56·7	7·91	9·5	0·51	0·43	0·47
27	30·9	12·6	56·5	9·55	15·5	0·46	0·39	0·42
28	31·8	11·1	57·1	9·9	20·5	0·30	0·26	0·28

TABLE V.—*Gasification of Medium-Temperature* (900° C.) *Coke at* 1000° C.

No. of Experiment.	Volumes of Wet Gas Constituents (Litres per Hour at N.T.P.) from 10 g. of Coke.							$CO + 2CO_2$.	$\frac{[CO]\,[H_2O]}{[CO_2]\,[H_2]}$.	$\frac{CO}{CO_2}$	P.Ct. of Steam Decomposed.
	CO.	CO_2.	$CO + CO_2$.	H_2.	H_2O.	$H_2 + H_2O$.	N_2.				
30	4·55	0·1	4·65	4·75	0·05	4·8	3·9	4·75	0·47*	45·5	99
31	7·7	0·9	8·6	9·4	1·6	11·0	3·0	9·5	1·46	8·6	85·5
32	10·35	2·65	13·0	15·8	9·7	25·5	6·5	15 65	2·4	3·9	62

* This figure is unreliable because of the difficulty experienced in measuring the small quantities of H_2O and CO_2 involved.

TABLE V.A.

No. of Experiment.	Dry Gas Compositions. Percentages by Volume.			Volume of Dry Water Gas Produced (Litres per Hour at N.T.P.).	Rate of Steam Supply (Litres per Hour at N.T.P.).	Time of Contact of Gases with Coke (Secs.).		
	CO.	CO_2.	H_2.			t_1.	t_2.	Average.
30	48·4	1·1	50·5	9·4	4·8	1·11	0·72	0·92
31	42·8	5·0	52·2	18·0	11·0	0·69	0·43	0·56
32	36·0	9 2	54·8	28·8	25 5	0·30	0·21	0·25

TABLE VI.—*Gasification of Medium-Temperature* (900° C.) *Coke at* 900° C.

Hahn's equilibrium value for the expression $\frac{[CO]\,[H_2O]}{[CO_2]\,[H_2]}$ at 900° C. as read from his graph of experimental results is 1·25.

No. of Experiment.	Volumes of et Gas Constituents leaving Tube (Litres per Hour at N.T.P.) from 10 g. of Coke.							$CO+2CO_2$.	$\frac{[CO]\,[H_2O]}{[CO_2]\,[H_2]}$	$\frac{CO}{CO_2}$	P.Ct. of Steam Decomposed.
	CO.	CO_2.	$CO+CO_2$.	H_2.	H_2O.	H_2+H_2O	N_2.				
33	0·52	0·3	0·82	1·15	1·46	2·6	2·94	1·12	2·22	1 7	44·2
34	1 03	0·88	1·91	2 72	5 25	8·0	5 9	2·79	2 26	1·2	34·0
35	1·17	1 15	2·32	3·34	6·84	10·2	5·3	3 47	2·08	1·0	33 0

TABLE VI.A.

No. of Experiment.	Composition of Dry Water Gas. Percentage by Volume.			Volume of Dry Water Gas produced (Litres per Hour at N.T.P.) from 10 g. of Coke.	Rate of Steam Supply (Litres per Hour at N.T.P.)	Time of Contact of Gases with Coke (Secs.).		
	CO.	CO_2.	H_2.			t_1.	t_2.	Average.
33	26·4	15·2	58 4	1·97	2·6	1·9	1·65	1 77
34	22·2	19·0	58 8	4·63	8·0	0·75	0 66	0 70
35	20·7	20·3	59·0	5·66	10·2	0·67	0·59	0·63

gasified at 1000° C. with two-thirds the velocity with which the bye-product coke gasified at the same temperature.

GASIFICATION OF MEDIUM-TEMPERATURE (900° C.) COKE AT 1000° C.

Results obtained when gasifying this laboratory coke at 1000° C. are given in Tables V. and V.a, and represented graphically in fig. 5. The steam decomposition with normal velocities was extensive, and the coke gasified extremely rapidly.

Hahn's equilibrium value for the expression $\frac{[CO]\,[H_2O]}{[CO_2]\,[H_2]}$ at 1000° C. as read from his graph of experimental results is 1·62.

GASIFICATION OF MEDIUM-TEMPERATURE (900° C.) LABORATORY COKE AT 900° C.

Results obtained when gasifying medium-temperature (900° C.) laboratory coke at 900° C. are given in Tables VI. and VI.a, and represented graphically in fig. 6.

The results of these experiments, as well as those recorded in Table V., using a steam velocity approximating to 5 litres per hour and a time contact of 1 second, show fair agreement with those of Bunte and Harries carried out at 900° C. and 1000° C. respectively; the steam decomposition being extensive at 1000° C., but not so at 900° C.

Results obtained by the Gas Investigation Committee [7] on blue water-gas generation on the works scale have been tabulated below in Table VII. with approximately comparable results from our laboratory investigation.

Comparison of experiments 30, 14, and 24, in which differently prepared cokes were gasified at 1000° C., show what an important bearing the method of preparation of a coke has upon its rate of gasification in steam, the composition of the water gas produced therefrom, and the extent of steam decomposition. For this reason, direct comparison of one set of results with another is difficult.

The non-attainment of equilibrium in the large-scale

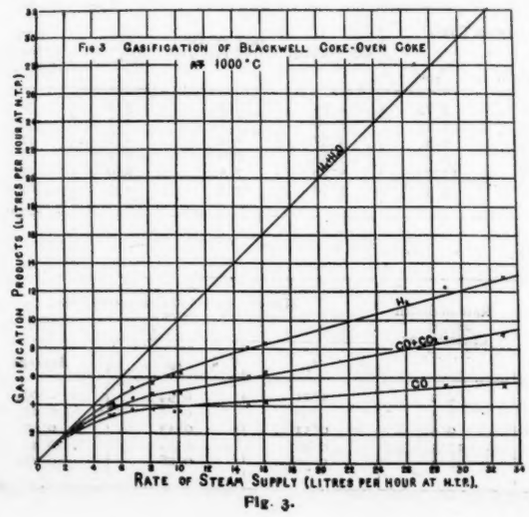


Fig 3 Gasification of Blackwell Coke-Oven Coke at 1000°C
Gasification Products (Litres per Hour at N.T.P.)
Rate of Steam Supply (Litres per Hour at N.T.P.)
H2O
H2
CO+CO2
CO

Fig. 3.

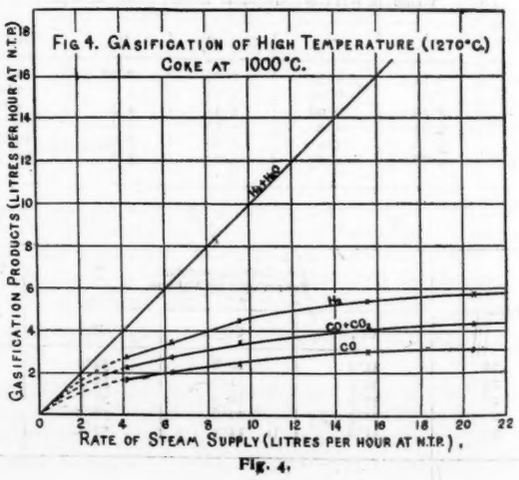


Fig 4. Gasification of High Temperature (1270°C.) Coke at 1000°C.
Gasification Products (Litres per Hour at N.T.P.)
Rate of Steam Supply (Litres per Hour at N.T.P.)
H2O
H2
CO+CO2
CO

Fig. 4.

TABLE VII.—*Large-Scale and Laboratory Results for Comparison.*

—	Test or Experiment No.	Composition of Dry Water Gas. CO.	CO_2.	H_2.	Volume of Dry Water Gas Produced (Litres/Hour at N.T.P.) from 10 g. of Coke.	Rate of Steam Supply (Litres per Hour at N.T.P.).	Volume of Dry Water Gas / Volume of Steam Supplied.	Average Time of Contact of Gases with Coke (Secs.)	P.Ct. of Steam Decomposed.	$\frac{[CO]\,[H_2O]}{[CO_2]\,[H_2]}$	$\frac{CO}{CO_2}$.
Tenth Report of the Gas Investigation Committee	A	39·6	4·7	46·8	..	..	1·5	2·2	57	6·4	8·4
	B	33·6	8·2	45·5	..	..	1·2	2·5	47	4·6	4·1
	C	38·7	5·5	50·1	..	..	1·7	1·8	67	3·5	7·0
	D	40·7	4·5	49·2	..	..	1·75	2·0	68	4·2	9·05
Average of tests in Sixth Report	..	41·4	4·2	49·2	..	..	1·83	2–2½	71	4·0	9·9
900 °C. coke gasified at—											
(*a*) 900° C.	33	26·4	15·2	58·4	1·97	2·6	0·76	1·77	44·2	2·22	1·7
(*b*) 1000° C.	30	48·4	1·1	50·5	9·4	4·8	1·96	0·92	99	0·47	44·0
Bye-product coke gasified at—											
(*a*) 900° C.	5	17·0	22 3	60·7	1·7	2·99	0·57	1·96	34·5	1·45	0·75
(*b*) 1000° C.	11	45·2	3 6	51·2	4·99	2·9	1·72	1·65	88	1·61	12·5
	12	44·8	3 8	51·4	5·25	3·1	1·69	1·72	87	1·65	11·7
	14	41·0	6·4	52·6	7·83	5·2	1·5	0·86	79·5	1·7	6·4
1270° C. coke gasified at 1000° C.	24	34·4	10·8	54·8	5·07	4·2	1·21	1·07	66·5	1·59	3·2

experiments of the Gas Investigation Committee is noticeable, and was advantageous from the standpoint of water-gas quality, because nearer approach to equilibrium would have led in the direction of $H_2O + CO \rightleftarrows CO_2 + H_2$ to a diminished CO/CO_2 ratio. At the same time, it indicates considerable thermal waste from the chemically inactive steam.

The general results of the Gas Investigation Committee,

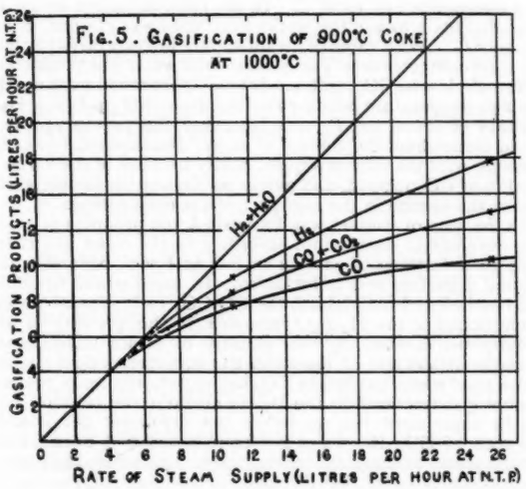


FIG. 5. GASIFICATION OF 900°C COKE AT 1000°C
GASIFICATION PRODUCTS (LITRES PER HOUR AT N.T.P.)
RATE OF STEAM SUPPLY (LITRES PER HOUR AT N.T.P.)
H₂+H₂O
H₂
CO+CO₂
CO

Fig. 5.

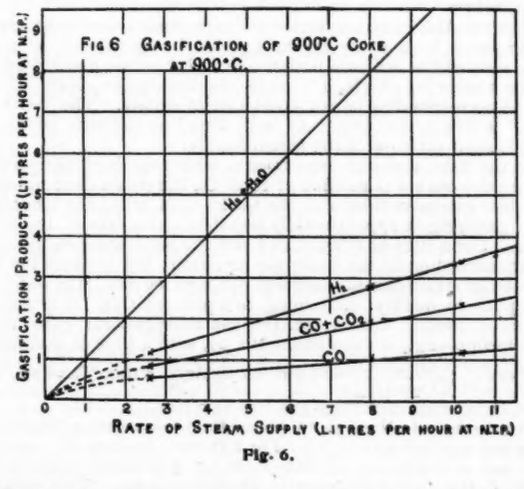


FIG 6 GASIFICATION OF 900°C COKE AT 900°C.
GASIFICATION PRODUCTS (LITRES PER HOUR AT N.T.P.)
RATE OF STEAM SUPPLY (LITRES PER HOUR AT N.T.P.)
H₂+H₂O
H₂
CO+CO₂
CO

Fig. 6.

as regards steam decomposition and gas compositions, indicate effective contact with carbon (giving high CO and low CO_2) of a portion of the steam, but a complete escape from interaction of another portion of the steam.

It is clear, especially from the results of Table III., that the effectiveness of steam decomposition in a fuel bed of fixed dimensions at any given temperature is determined by the rate of steam supply divided by the volume of free space in the fuel bed (which quotient is the time of contact of the steam with the carbon when no diluent gas is present) independently of whether that steam supply is diluted with nitrogen or not.

REFERENCES.

(1) Gas Research Fellowship Report 1923. Transactions of the Institution of Gas Engineers, 1922-3, pp. 376-415.
(2) Bunte and Harries. Journ. für Gasbeleuchtung, 1894, p. 81.
(3) Hahn. Zeit. für physik. Chemie, **42**, 1902, p. 705; **44**, 1903, p. 513.
(4) Farup. Zeit. für anorg. Chemie, **50**, 1906, p. 276.
(5) Clement, Adams, and Haskins. U.S. Bureau of Mines, 1911, Bulletin No. 7.
(6) Haslam, Hitchcock, and Rudow. J. Ind. and Eng. Chem., **15**, 1923, pp. 115-121.
(7) Sixth Report of the Gas Investigation Committee. Transactions of the Institution of Gas Engineers, 1920-1, pp. 255-325.
Tenth Report of the Gas Investigation Committee. Transactions of the Institution of Gas Engineers, 1922-3, pp. 293-375.

Prof. COBB, in introducing the report, said: In the work leading up to this in the paper read by Dr. Pexton and myself last year, on the volatilization of carbon in steam, we dealt more particularly with the liberation of nitrogen and sulphur from the coke and the formation of ammonia and sulphuretted hydrogen. The importance of the amount of steam which escaped through the carbon undecomposed was brought out clearly, especially as affecting the yield of ammonia obtainable. It was also made clear that cokes prepared at different temperatures do not behave alike. Our attention during the past twelve months has been focussed upon the rates of gasification and the composition of the gas produced. I may note several points which emerge, and are dealt with more fully, either in the Introduction or Summary or in the text of the paper.

In the first place, in none of our laboratory experiments was a good water gas low in CO_2 obtained at a temperature of 900° C. At 1000° C. the water gas was good or bad, according to the conditions of operation. With a low rate of steaming, the equilibrium ratio among the gaseous products was attained. Moreover, there was very little undecomposed steam, and as a consequence a good quality of water gas was made low in CO_2. With a rather higher rate of steam supply the equilibrium condition was attained in the gases, but there was more undecomposed steam than before, and the effect of this was to give a gas which, though of equilibrium composition, was no longer low in CO_2 and was not, therefore, a good water gas. Equilibrium presumably was attained very rapidly in the surface films of gas next to the coke, and the interaction there with undecomposed steam lowered the quality of the gas. The mere attainment of the equilibrium ratio was not sufficient to guarantee a good quality of water gas. When still more steam was supplied, some of it not only remained undecomposed, but did not interact up to the equilibrium point with the other gases generated, and so the product was one in which the equilibrium ratio had not been attained, and consisted of a poor water gas high in CO_2 and in undecomposed steam. With a harder coke, the rate of gasification was lowered, and the rate of interaction in the gases along the surface of the coke lowered also. More steam escaped undecomposed, and the condition was further from equilibrium.

On comparing the laboratory results with those obtained in the large-scale experiments of the Gas Investigation Committee (see Table VII.) there is one remarkable difference, because in the large-scale experiments, though there is a large proportion of steam undecomposed, the water gas is low in CO_2, and good in quality. It is just as if a portion of the steam had been given complete

facilities for interaction with carbon and attainment of equilibrium in the products, while another portion of the steam had been by-passed. Presumably this difference is to be explained by the fact that in the small-scale experiments in which the steam passed through a few inches of coke dust the surface of coke was so large and the interstices were so small that interaction of undecomposed steam with the first products of gasification was facilitated, whereas in the large-scale experiments the gas made on the surface of the coke (low in CO_2) mixed more or less with the steam in the interstices between the particles of coke, and these were relatively so large that there was little surface action brought into play and little interaction between the steam and the gas, so that the resulting product was low in CO_2—a mixture of good water gas with undecomposed steam. The remarkable thing here is that the securing of a good quality of water gas on the large scale is dependent upon the fact that equilibrium is not attained; if it were attained, the water gas would be bad. On the other hand, the passage of so much steam undecomposed does, of course, involve an appreciable thermal loss of heat simply convected away from the generator by the steam. Another way of expressing the difference between the large-scale results and those obtained with finely-divided coke in the laboratory would be to say that whereas on the large scale the steam underwent decomposition by direct interaction with solid carbon or escaped decomposition altogether, in the laboratory experiments it was liable to undergo extensive decomposition by gaseous interaction in the gas films next to the carbon, according to the equation

$$CO + H_2O \rightarrow CO_2 + H_2.$$

Another point of interest arose in some experiments in which the time of contact of the steam with the coke was reduced by mixing the steam with inert nitrogen, which meant that if the same amount of steam were to be supplied per hour in the diluted gas, it had to pass through the apparatus much more quickly, so that the time of contact was smaller. It was found, however, that this shortening of the time of contact made very little difference, and that the percentage of undecomposed steam, the rate of gasification, and the composition of the gas remained substantially unaltered, so long as the actual amount of steam supplied was the same. The explanation is probably connected with the fact that the gasification must take place through a surface film of gas covering the coke, and that when the stream of steam and nitrogen was flowing through the bed more quickly its motion was more turbulent, and its thinning or penetrating effect upon the film was increased to such an extent as to compensate for the diminished time of contact, so that in the end the rate of gasification was the same for the same steam supply, though the time of contact was so much smaller. It is easy to see that some compensation of this sort is likely to occur, but it is not so easy to see why compensation should be quantitative. A somewhat similar phenomenon of a purely thermal kind has, however, been investigated.

In a paper read by Prof. Osborne Reynolds in 1874, and referred to in Prof. Perry's book on the "Steam Engine," he points out the complication in the transmission of heat from flue gases to water in a boiler, which arises from the presence of a stationary film of flue gas on the boiler plane, and concludes that within limits, whatever the speed of the gas through the boiler tube, it should leave at the same temperature. Involving the same idea, Dr. Stanton, in 1897, described how he had forced water at different temperatures through two concentric pipes, and found that *at quite different speeds* the change of temperature produced in a given length of pipe was pretty much the same. Here again the stationary film was of importance; but this time one of liquid next to metal.

Another interesting point arising in connection with the experiments we have described in this Report (and also in connection with the previous Gas Research Fellowship Reports in which Dr. Monkhouse and Dr. Pexton in turn have collaborated with me) is how far have the results obtained been influenced by the ash constituents of the coke.

Dr. PEXTON (Gas Research Fellow), summarizing the report, said: During the past year Prof. Cobb and I have continued our examination into the process of gasifying coke in steam, in particular, with reference to the composition of water gas produced and the proportion of steam decomposed. In order that our results should have reference to those previously reported by us, we have continued to use cokes all of which were prepared from Blackwell (Derbyshire) coal. Because of the important differences we showed to exist between the rates at which high and medium temperature cokes prepared from the same coal gasify under similar conditions of temperature and rate of steam supply, we chose to examine two cokes prepared in the laboratory at 900° and 1270° C. respectively, and in addition a works coke prepared in ovens on the large scale from a similar coal to that used in our laboratory preparations. The laboratory cokes were made in crucibles holding approximately 500 grammes of coal, the carbonization being carried out in a large laboratory furnace, and temperatures being taken on the outside of the crucibles. The latter were brought to the desired temperature in three hours, and maintained at this value for four hours, after which they were withdrawn from the furnace to cool. The cokes were crushed and graded; and it is important to note that for our experiments the limits of size used were $\frac{1}{10}$ in. and $\frac{1}{4}$ in. (in some cases $\frac{1}{2}$ in.). The method of experiment has been to lead a constant stream of nitrogen saturated with steam through a closely packed column of coke (approximately 3 in. in length and 1 in. in diameter) maintained at constant temperature. The water gas, nitrogen, and excess steam were led through U tubes containing (*a*) calcium chloride, and (*b*) solid caustic soda, into a gasholder where volume measurements were taken and from which samples were withdrawn for analysis. The excess water vapour and the carbon dioxide were determined gravimetrically; these measurements being converted into volumes, and the CO and H_2 were estimated volumetrically.

The general scheme running through the various series of experiments has been to increase the rate at which steam is supplied to a column of coke of fixed dimensions, and to observe the resulting change in gas composition and steam decomposition.

In the first series of experiments the works oven coke was gasified at 900° C. The object of this series of experiments was to ascertain through comparison with the experiments reported last year, what was the extent of steam decomposition in those experiments where the quantity of ammonia preserved was appreciable (it being remembered that very little ammonia survived under any conditions at temperatures above 900° C.). With a normal time of contact (2 secs.—*i.e.*, approximately 5 litres of steam per hour in our experiments) the works oven coke decomposed 25 p.ct. of the steam supplied. From our previous work one might expect, with such a rate of steam supply, 30 to 50 p.ct. of gasified nitrogen to be recovered as ammonia, but it will be seen that the sacrifice in undecomposed steam is enormous, and the quality of water gas out of the question (15 p.ct. of CO, and 24 p.ct. of CO_2). In the experiments recorded in Table VI., where medium temperature (900° C.) coke was gasified at 900° C. with a rate of steam supply of 5 litres per hour, 40 p.ct. of steam was decomposed. The ammonia yield was probably lower than for the works oven coke under similar conditions, while the water gas was slightly better (17 p.ct. of CO_2, and 24 p.ct. of CO). Combining these two series of experiments with those reported last year, it seems clear that the production of water gas of good composition is unlikely under conditions which favour ammonia preservation.

All the remaining series of our experiments have been conducted at a temperature of 1000° C. In the most extensive series, No. 2 (experiments 9 to 23), the works oven coke was gasified in steam at 1000° C. With rates of steam supply below 2 litres per hour—*i.e.*, time contacts up to 3 or 4 secs.—the water gas produced was extremely low in CO_2, and conditions approached very nearly to the high temperature primary reaction $C + H_2O \rightarrow CO + H_2$. As the rate of steam supply was increased, the percentage decomposed diminished, the amount of steam decomposed, however, increasing with the rate of supply, partly because of the large proportion of CO_2 formed, and partly because of the further gasification of the carbon in the rear part of the coke column.

As the time of contact was diminished, the products of gasification were still in equilibrium according to the water-gas reaction right down to times of contact so low as $\frac{1}{2}$ sec., beyond which a gradual departure was to be noted. In cases where equilibrium was reached and maintained, the $CO \cdot CO_2$ ratio was of necessity proportioned to the $H_2 \cdot H_2O$ ratio—*i.e.*, to the quantity of steam decomposed divided by the quantity of steam undecomposed. Thus the attainment of the water-gas equilibrium does not mean that a good water gas low in CO_2 has necessarily been produced; this being determined by the $H_2 \cdot H_2O$ ratio in the reaction zone—*e.g.*, in experiment No. 19, where the dry water gas contained 12·5 p.ct. of CO_2, the water-gas equilibrium had been attained, but the steam decomposition was not very extensive (62 p.ct.). It should here be noted that the high iron content of the coke ash (approximately equivalent to 30 p.ct. of Fe_2O_3) was probably partly responsible for the rapid attainment of the water-gas equilibrium.

The results of any one series of experiments are most clearly assimilated by a study of the graphical representations made. The ratio of the ordinate under each "H_2" curve, divided by that under each "H_2 and H_2O" curve, represents the steam decomposed corresponding to any given rate of supply. The "CO and CO_2" curve is important as indicating how the rate of carbon gasification varies with the steam supply.

In the third series of experiments, where the high-temperature laboratory coke was gasified at 1000° C., the steam decomposition was less extensive than with the works oven coke; the laboratory coke gasifying at approximately two-thirds the rate of the works coke. For a time of contact of 1 sec. the products were in equilibrium according to the water-gas equation; but because the proportion of steam decomposed was not high (66 p.ct.), the water gas was poor in quality, containing 10·8 p.ct. of CO_2. For smaller times of contact than 1 sec. the gas compositions were not in equilibrium—*e.g.*, in experiment No. 27, with a time of contact of 0·4 sec., $\frac{(CO)\ (H_2O)}{(CO_2)\ (H_2)}$ was 4·6, as against K1000° C. = 1·6, and the CO_2 content of the dry gas was 12·6 p.ct.

In experiments Nos. 30 to 32 medium-temperature laboratory coke was gasified at 1000° C. For a time of contact of 1 sec. the CO_2 was as low as 1 p.ct., as against 10·8 p.ct. noted above in the case of the high-temperature laboratory coke. The rates of gasification for the carbon of the 900° C. coke, the 1270° C. coke, and the works oven coke at 1000° C. for a rate of steam supply of 5 litres per hour (*i.e.*, approximately 2 sec. time of contact) were as 10 : 7 : 5.

In Table VII. a comparison of our experimental results for the three cokes with those obtained by the Gas Investigation Committee on the large-scale work is made. The chief difference between the two sets of results is that, whereas in our own experiments at 1000° C. for a time contact of 2 sec., the gas compositions

in every case satisfied the equilibrium expression, those of the Gas Investigation Committee led to high values of $\frac{(CO)\ (H_2O)}{(CO_2)\ (H_2)}$; and, as Prof. Cobb has pointed out, we attribute this to some steam having passed through the fuel bed in the large-scale experiments without adequate opportunity of reacting with the carbon and the gaseous products of reaction.

Another point brought out more clearly in Table VII, is the wide extent to which the water-gas composition does vary when differently-prepared cokes from the same coal are gasified under precisely similar conditions.

The PRESIDENT: I am sure we are all very much obliged to Prof. Cobb for his interesting and illuminating introduction to the report, and also to Dr. Pexton for his summarizing of it. I have pleasure in moving that the report be adopted.

Mr. W. J. SMITH (Bolton): I have pleasure in seconding this. There is one point, and that is with regard to the temperature of 1000° C. as mentioned for gasification of the coke. Was this temperature maintained during the whole time of the experiment, or was there some variation when the steam flow was increased?

Dr. PEXTON: The column of coke was so small that it was quite easy, by the arrangement we had, of an electric furnace, to supply the heat which was absorbed by the endothermic reactions, and to keep the temperature at 1000° C. constant throughout the fuel bed.

Mr. SMITH: I would like to know what is the highest efficiency that has been obtained in the gasification with steam, in actual laboratory practice. Percentages of 45, 50, and 60 have been mentioned.

Dr. PEXTON: The largest proportion of steam decomposed in any one series of experiments was in the experiment in which the medium-temperature laboratory coke was gasified at 1000° C., and there the percentage of steam decomposed was 99 p.ct., corresponding to a time of contact of 1 sec., which is less than one gets on the average large-scale water-gas plant.

Mr. H. D. MADDEN (Cardiff): There is one question, and that is on the application of this investigation to practical working. Can Dr. Pexton tell us what in his opinion, as the result of his experiments, is the size of coke best suited to a water-gas generator? We have our own opinions, but I am afraid they are not always authentic; and if Dr. Pexton could give us some idea on this matter, it might help us to reduce the carbon dioxide, and get a higher calorific value gas.

Mr. J. FERGUSON BELL (Derby): I take it that all the experiments mentioned in the report were carried out on one type of coal. It would be interesting to have results on a variety of coals.

Dr. TRAVERS: One thing about this report is that it contains one little touch which is missing from so much of the previous work on the subject, and that is that we are dealing with a coke which is a definite coke. If we take some of the papers referred to in the report, it is found that a material described as coke is dealt with, but they do not say how it was obtained or what was its previous history. No idea is given of (say) three or four different types of material produced in a certain way, the information concerning which it is possible to collate. Therefore the results in this report, of practical experience, are of particular interest to my colleagues and myself. There is one point in connection with Table VII. I do not see that the experiment conducted at 1000° C. and the experiments of the Tenth Report are comparable; and I am not sure at the moment whether I did not include something in my printed paper this morning to suggest that in a water-gas plant equilibrium appears to be obtained at a very high temperature, and that is why in the last column but one you get these high values of equilibrium constants. For some reason—and we shall have to go into this matter further—it appears that the equilibrium does not reverse as the gas passes through the upper layers of the fuel bed; and therefore, though the mean temperature of the fuel bed may be comparable, we have really no equilibrium condition corresponding to the high temperature at which the action is at a maximum. The whole matter is an extremely complex one, and one fears to use the term "normal" in connection with any water-gas process, because even in this paper you see the very complicated factors and conditions which come into play. It shows definitely that you may have very different rates of change simply by mechanical difference in the life of coke. Then, again, the quantity of ash affects the rate at which the equilibria are established in the fuel bed.

Dr. PEXTON, replying to the discussion, said: In reply to Mr. Madden as to what is the most suitable size of coke to use in a water-gas generator, it would appear from our results that the first thing to obtain is a uniform fuel bed; and I think the answer to that question lies in the determination of the best size which will give a uniform fuel bed without introducing other difficulties. I am afraid I have not had sufficient experience on large-scale water-gas manufacture to be able to answer that point as to what will prove the most suitable size of coke to produce a uniform fuel bed, but naturally the smaller the size of coke the more uniform the fuel bed, though one cannot go on reducing the size indefinitely, because other difficulties will crop up. Like most questions of this kind, it is a compromise which is only solved by practical experience. Regarding the question raised by Mr. Ferguson Bell, as to the coal used, it was one sample only. Dr. Travers' remarks and suggestions are very valuable to us.

Dr. PARKER: I am afraid I am rather late in rising to speak, but I was looking up some figures in the Sixth Report on water-gas in connection with the point Dr. Travers has raised. He mentioned that the equilibrium constant in the manufacture of water-gas is very much higher in the small scale experiment which Dr. Pexton has carried out; and he explained the difference by the fact that you get equilibrium at a high temperature, and then the reaction is frozen in the upper layers of the bed. I agree with this to a certain extent, but I also think that Prof. Cobb's explanation of greater turbulence in small-scale experiments also comes into play, because in working out equilibrium constants and water-gas reactions you have CO, CO_2, and steam. If you start with steam in the first place and no CO or CO_2, it is quite clear that to get equilibrium you must have a definite proportion of CO and CO_2. The percentages of CO and CO_2 will determine the equilibrium, but you must have a certain percentage of undecomposed steam. You can work at the temperature corresponding with the CO and CO_2 produced on the large-scale, and you will probably get a temperature of 1000° C. You then look up the curve of undecomposed steam and you will find it does not agree with 1000° C. but something very much less. I think, therefore, that the two explanations come into play; at the same time, the freezing out of the reaction, as I believe we mentioned in an earlier report, and is mentioned by Dr. Travers, comes in with the less intimate contact mentioned by Prof. Cobb in his introduction.

The report was adopted.

Prof. COBB writes: Dr. Travers makes the interesting suggestion that the reason for the high values of the $\frac{[CO]\ [H_2O]}{[CO_2]\ [H_2]}$ ratio obtained on the large scale and reported in Table VII., is that equilibrium is attained in the hottest part of the fuel bed where the temperature is so high that the ratio $\frac{[CO]\ [H_2O]}{[CO_2]\ [H_2]}$ has a correspondingly high value. This is opposed to our own view that the high value of the ratio is mainly due to undecomposed steam with which no equilibrium conditions have been attained. The suggestion is not one which we can accept as having more than a very limited application. Such ratios running from 6·4 to 3·5 as were obtained on the large scale would correspond with temperatures outside the range of water-gas practice. It is to be remembered that Hahn's highest figure experimentally determined was 2·45 for a temperature of 1405° C. Much higher temperatures may be attained locally and for a time during the air blow, but they cannot persist during the run under the cooling action of the steam, and it is to be borne in mind that the ratios given in the table, and the gas compositions, are not those momentarily attained, but averages for complete periods of gas making during each of which the temperature is steadily falling. The condition of the clinker confirms this view, though exact temperature measurements of the interior of the fuel bed have still to be made. Coal ash is not a highly refractory material; and at any temperature giving, for example, a ratio of 4 (1600° C.) most coal ashes would be running like water—a condition which can, of course, be attained in some circumstances by continuous blowing, but not with the rapid alternations of a water-gas plant. Moreover, I must say that even if equilibrium had been attained corresponding with the very high temperatures in the fuel bed suggested, I do not think it would have been "frozen" there. The equilibrium would have been mobile in the presence of hot coke until the stream of gas reached a considerably lower temperature, and following out (as we have not attempted to do) the action from layer to layer of a water-gas generator, no doubt something of that kind occurs. The final composition of the gas, however, with its high ratio $\frac{[CO]\ [H_2O]}{[CO_2]\ [H_2]}$ and undecomposed steam seem to me to receive a satisfactory explanation on the lines we have suggested.

THE CONSTRUCTION OF NEW COAL-GAS WORKS AT GARSTON.

By R. E. GIBSON, of Liverpool.

The construction of entirely new works is not in these days an event of frequent occurrence. When such construction takes place, it is helpful to add to the common stock of knowledge and experience by recording any special features and circumstances in connection therewith. With this object in view, and at the request of the President, this paper has been prepared in the hope that it may evoke a useful discussion.

One can learn much from the interchange of experiences in engineering matters. There are *pros* and *cons* to be considered in almost every scheme; this is so even in the smaller details, while local conditions and circumstances almost invariably have to be reckoned with.

It is not the author's intention to describe the new coal-gas works at Garston in detail, as a description has already been published in connection with the visit of the Manchester District Institution of Gas Engineers to Garston last year (see "JOURNAL," May 16, 1923, page 411), but to deal more particularly with the reasons for the adoption of the various kinds of plant and the different forms of construction, and to give some particulars as to the results obtained.

First, it may be well briefly to review the circumstances which led to the erection of the new works.

During the winter of 1914-15 a large increase in the consumption of gas took place, the maximum weekly delivery being 15·7 p.ct. greater than the previous record weekly consumption of the year before. The margin of spare plant was thus seriously encroached upon, and the provision of more plant became somewhat urgent. Application was therefore made in 1916 to the appropriate Government Departments for permission to erect new works and to raise the necessary capital for them. The conditions then prevailing due to the war were such that the Government could not see their way to grant permission, and all that could be done at the time was to enlarge certain water-gas sets and to work the existing coal-gas plant to the best advantage possible under the circumstances.

During the war period and for some time afterwards the Liverpool Company were further handicapped by a greatly reduced make of coal gas and also of water gas, due to the very bad quality of the coal supplied under the Coal Transport Reorganization Scheme, and to the inferior coke produced therefrom. Notwithstanding the great difficulties referred to, full supplies of gas were maintained throughout the war period and since, thanks to the unceasing efforts of the staff.

The long-deferred erection of new works was put in hand at the end of 1919, with the intention of completion by the autumn of 1921, but, owing to unavoidable delay on the part of the contractors, they were not put in operation until March, 1922. It was unfortunate for the Company that the construction of the new works had to be undertaken when prices of materials and labour were very high. As the costs were quite abnormal and would serve no useful purpose as a guide to-day, no mention will be made of them in this paper.

Choice of Plant.—In 1919, the proportion of water-gas plant to coal-gas plant was somewhat high, being in the ratio of 48 to 52, and the cost of production of water-gas per therm was much greater than that of coal-gas. It was therefore felt desirable to reduce the proportion of water-gas by installing coal-gas plant. A further strong reason for the adoption of coal-gas plant was the fact that the Garston works up to this time was purely a water-gas station, the whole of the coke required in the water-gas plant being supplied from the other coal-gas works, involving great expense in carriage and handling charges. By arranging for the coke to be made at Garston, it was estimated that the saving on this item alone would be £13,000 per annum.

In determining the type of carbonizing plant to be adopted, there were two main factors to be considered:

(1) It was obvious that a system should be adopted which would not tend to increase the proportion of water-gas. A straight coal-gas plant was therefore to be preferred, rather than one in which steaming would be resorted to.

(2) Large quantities of gas oil had hitherto been necessary to enrich the water-gas and maintain the quality. The price of this raw material soared upwards to as high as 1s. 6d. per gallon during the war, and there was no assurance that the price would stabilize at a reasonably low figure in the future.

A system which would do away with the necessity for using oil was to be welcomed, and the best means of achieving this object appeared to be the production of a rich coal-gas in horizontal retorts using good coal and some cannel, whereby gas of 550 to 700 B.Th.U. could easily be obtained.

As a very large proportion of the coke produced would be used in the existing water-gas plant, it was desirable that the coke should be of suitable quality, and as free from breeze as possible.

Coal-gas plant with horizontal retorts fulfilled the conditions, and had further advantages when compared with the vertical system as regards lower capital cost, greater ease of control and wider choice of coals, while greater freedom was secured in obtaining tenders.

These considerations were deemed to outweigh any advantages that vertical retorts might possess over horizontals.

Choice of Site.—The large piece of land at Garston, the first portion of which was purchased as far back as the year 1870 for gas-works purposes, 32½ acres in extent, will provide room for all the extensions that may be needed for some years to come. A partly developed road runs from the works gates on the south-west side towards the L.M. & S. Railway on the north-east side, dividing the land into two parts. The portion on the north-west side of the road was already occupied to a large extent by water-gas plant, and it had been laid out with a view to doubling the capacity of the water-gas plant at some future time. The portion on the south-east side was undeveloped.

After allowance had been made for the water-gas extensions just referred to, there was still sufficient room on the north-west side for a coal-gas plant of 5,000,000 c.ft. capacity per day. Furthermore, it was essential that the new retort-house should be in close proximity to the water-gas generator house so that the conveyance of coke from the one to the other would be over as short a distance as possible. The new retort-house was therefore placed in line with the generator house, and within reasonable distance of the railway siding, the other plant being arranged as shown on the plan (fig. 1). It will be seen that the site has been utilized with as little waste as possible; compactly and yet conveniently.

The site contains oil storage tanks, accommodating 6000 tons of oil, a gasholder (A) of four million c.ft. capacity, and space for another larger holder (B) adjacent to the existing one. The provision of further gasholder accommodation was deferred, but has since been dealt with, and a new spirally-guided holder is now under construction, but not on the site just mentioned, for reasons which will be given later.

Foundations.—Trial holes were excavated, and it was found that the first two to three feet were clay, then sand, and below that good red sandstone rock at a depth of about 28 ft. on the site of the retort-house, and from 6 to 27 ft. on the site of the purifying house and other buildings.

As it would have been a costly matter to have taken the foundations of the retort-house down to the rock, it was decided to spread the weight by means of mass concrete, and this was done to a depth below datum of 8 ft., the pressure allowed being 1·28 tons on the square foot. In the case of the purifiers, however, the foundations were carried down to the rock in each case.

The only troublesome part was that at the end of the exhauster house, where, in excavating for the tar and liquor tanks to a depth of 21 ft., a bad patch of ground was encountered. To give the necessary support to the

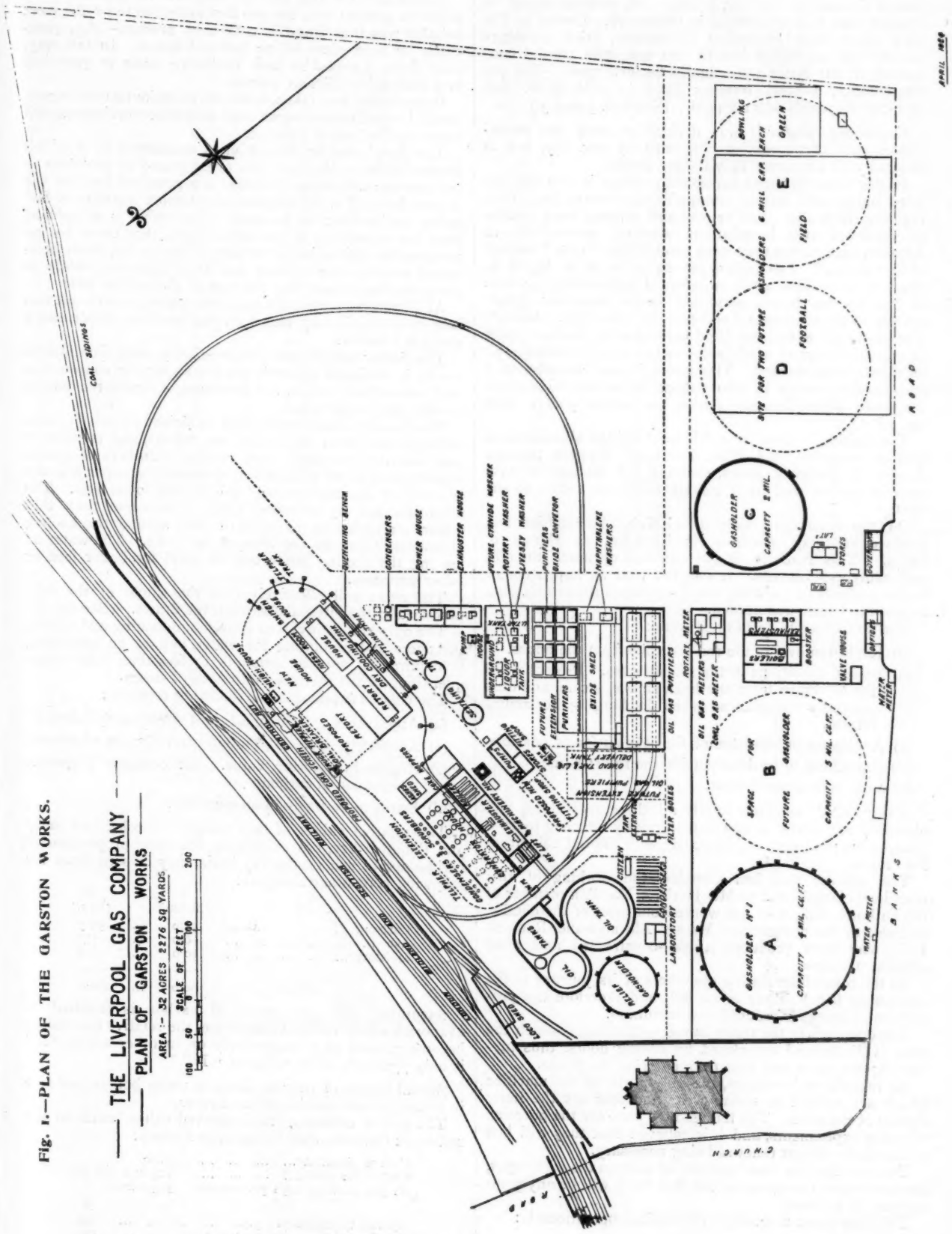


Fig. 1.—PLAN OF THE GARSTON WORKS.

end wall of the exhauster house, a mass-concrete pier and reinforced concrete beam were constructed as shown in fig. 2. [This figure is not given in the "JOURNAL."]

Buildings.—Before deciding on the type of buildings to be adopted, experiments were made in concrete construction at Garston to find out whether this method would be cheaper than that of building in brickwork. Owing to the high prices then prevailing for cement, brick buildings worked out somewhat less in cost and, after careful consideration, the latter were finally decided upon. For the retort-house, a steel framing filled in with 9 in. and 4½ in. brick panels was adopted. (See figs. 3 and 5.)

Carbonizing Plant.—It was decided to erect two retort-houses each of 2½ million c.ft. capacity per day, but to proceed with one house only for the present.

In this house fourteen horizontal settings in two benches were built, each setting containing 10 retorts in 5 tiers (140 retorts in all). The retorts and settings were similar to those of two installations working successfully at Linacre, except that they were arranged in "tens" instead of in "eights." The retorts are 24 in. by 18 in by 22 ft. long of Ω section, each capable of carbonizing 35 cwt. of coal per day in two periods of twelve hours, or 45 cwt. per day in three periods of eight hours. (See figs. 3 and 6.*) The producers have been fitted with sloping fire-bar grates of special design to obviate the necessity of clinkering, no false bars being needed. This form of grate has effected a considerable saving in labour since its introduction in all the works of the Company during the last few years. (See fig. 3.)

The stoking is done by a Fiddes-Aldridge simultaneous stoking machine, fed from overhead hoppers through A. and G. automatic doors, enabling the machine to take each charge of coal as it travels from one retort to the next.

On the discharging side, a "G.N." coke-handling and producer-charging machine is installed, as shown in fig. 3. This machine is the outcome of much thought and many experiments. It was felt that an improvement in the methods of handling red-hot coke on the discharging side of the bench was needed.

The conditions to be fulfilled were:

(*a*) Rapid removal of the red hot coke from the house.

(*b*) Better conditions in the retort-house. Protection of the workmen from the heat, smoke, steam, and dust generally experienced when discharging horizontal retorts.

(*c*) Avoidance of breakage of the coke as far as possible.

(*d*) Quenching to be done outside the retort-house.

(*e*) Low maintenance costs.

The "G.N." machine fulfills all these conditions, and also does something it was not originally intended to do—charges the producers expeditiously with red-hot coke from the retorts.

The success that has attended the working of this machine is largely due to Mr. Herbert Nicoll, a member of the author's staff, who has worked out most of the details, and also to the contractors, Messrs. Aldridge and Ranken, Ltd., who have produced a well-constructed and most efficient machine.

As the coke slides during the whole of its journey to the quenching bench, there is no fall, and therefore the production of breeze is reduced to a minimum.

The openings in the retort-house wall through which the coke is discharged are closed by sliding doors, thus preventing the steam and dust from entering the house.

As regards maintenance, the only parts of the machine which are subject to severe wear and tear are the inner linings of the tube. The linings now used are the outcome of many experiments, and it is believed that they will last a long time without renewal being necessary.

There is also the usual amount of wear on the wire ropes, but otherwise it is not expected that there will be any great expense in up-keep.

The time taken to perform the various operations is:

Discharging a top retort	25 seconds
Discharging a bottom retort	35 ,,
Travelling along the house	2 ft. per second

* This drawing is an elevation of the retort-house and carbonizing plant. It is omitted from the report, but will appear in the "Transactions."

This method of coke handling was fully described in an exceedingly valuable paper by Mr. S. E. Whitehead, B.Sc. Eng., of Portsmouth, to the Southern Association of Gas Engineers and Managers in March last, so that it is unnecessary to add anything further.

Quenching.—Of the various methods of quenching by water in general use, the one that appeared to be the most suitable was that found in coke-oven practice—viz., quenching by hose pipes on an inclined bench. In this way, coke from Lancashire and Yorkshire coals is quenched in a thoroughly efficient manner.

Opportunity was taken, however, to make further experiments in the dry-cooling of coke, following previous experiments carried out at Linacre.

The time is not far distant when consumers of coke will become alive to the fact that every pound of moisture in the coke not only takes the place of a pound of fuel, but has to be driven off at the expense of a further quantity of fuel before useful work can be done. The author is of opinion after his experience at the other works, that there are no insuperable difficulties in the way of producing from horizontal retorts coke entirely free from moisture, while at the same time conserving the heat of the red-hot coke.

At Garston an attempt has been made to carry out this idea in a simple way based on the previous experiments made at Linacre.

The Sulzer system, now in operation at some Continental works, is designed to carry out dry cooling in conjunction with waste-heat boilers, but involving of course the use of considerably more plant.

The Garston installation is of sufficient capacity to deal with the coke from one bed of ten retorts, and consists of two electrically-welded steel cooling chambers of special construction, fitted with sliding doors at the upper end and self-sealing mouthpieces and lids at the lower end. The chambers are so arranged within a concrete tank that water, circulated in passages in and around the cooling chambers, takes up the heat of the coke. The water on leaving the cooling tanks may be used for boiler feed or other purposes.

The plant will effectively cool the whole of the coke produced in the intervals between the draws. (See fig. 4.)

The only labour involved consists in opening and closing the doors and regulating the water, and, as no quenching is required, it actually amounts to less than with water quenching, while there is an absence of steam.

The coke is superior in the following respects:

(*a*) Appearance. (It is of a bright silvery-grey colour.)

(*b*) Absolutely dry. (It contains no moisture whatever.)

(*c*) Higher in calorific value. (It contains a greater proportion of carbon.)

(*d*) Burns more freely in an open fire.

The relative values of two samples of coke, one moist and the other dry, but containing the same proportions of carbon and of ash on the dry basis, may be seen from the following percentage analyses:

	A (Moist.)	B (Dry.)
Carbon	74·0 ...	92·5
Ash	6·0 ...	7·5
Moisture	20·0 ...	0·0
Total	100·0 ...	100·0

Assuming that one pound of carbon is required to evaporate every 10 lbs. of moisture, the relative fuel values become 72 and 92·5 respectively or, in other words, "A" is only 77·8 p.ct. of the value of "B."

Actual results of tests at Garston under boilers and also in water-gas sets confirm these figures.

The cost of obtaining the improved value, based on the results at Garston, may be taken as follows:

Cost of plant, say...	£600
Coke to be cooled...	11½ tons per day.
At 300 working days per annum	3,450 tons.

	£
Interest on capital at 5 p.ct.	30
Repairs and depreciation at 20 p.ct.	120
Cost of circulating cooling water, 300 days at 5s. per day	75
Total	£225

£225 ÷ 3,450 tons = 1s. 3½d. per ton.

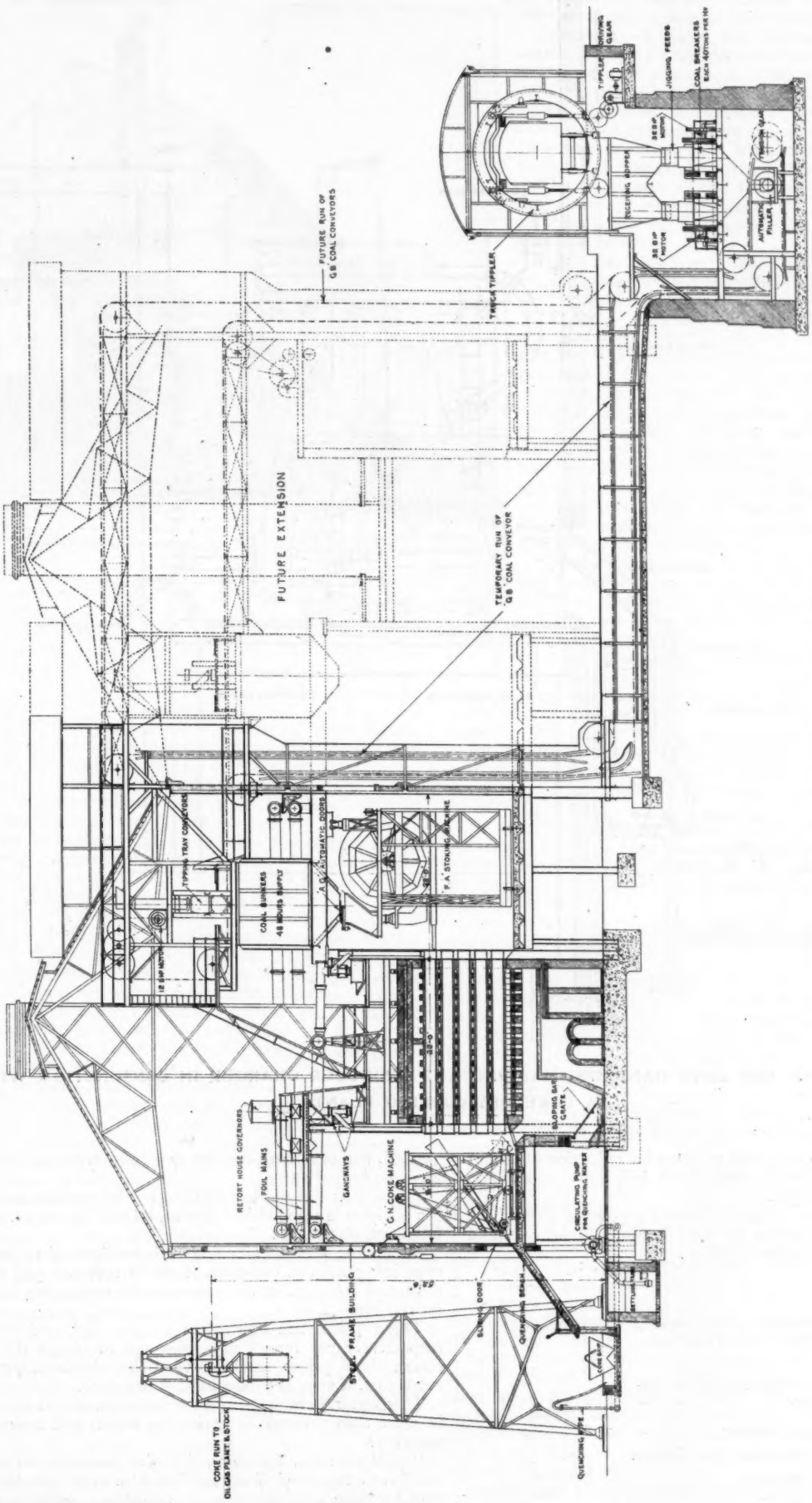


Fig. 3.—SECTION THROUGH RETORT-HOUSE.
Showing Coal and Coke Handling Plant and Future Extension.

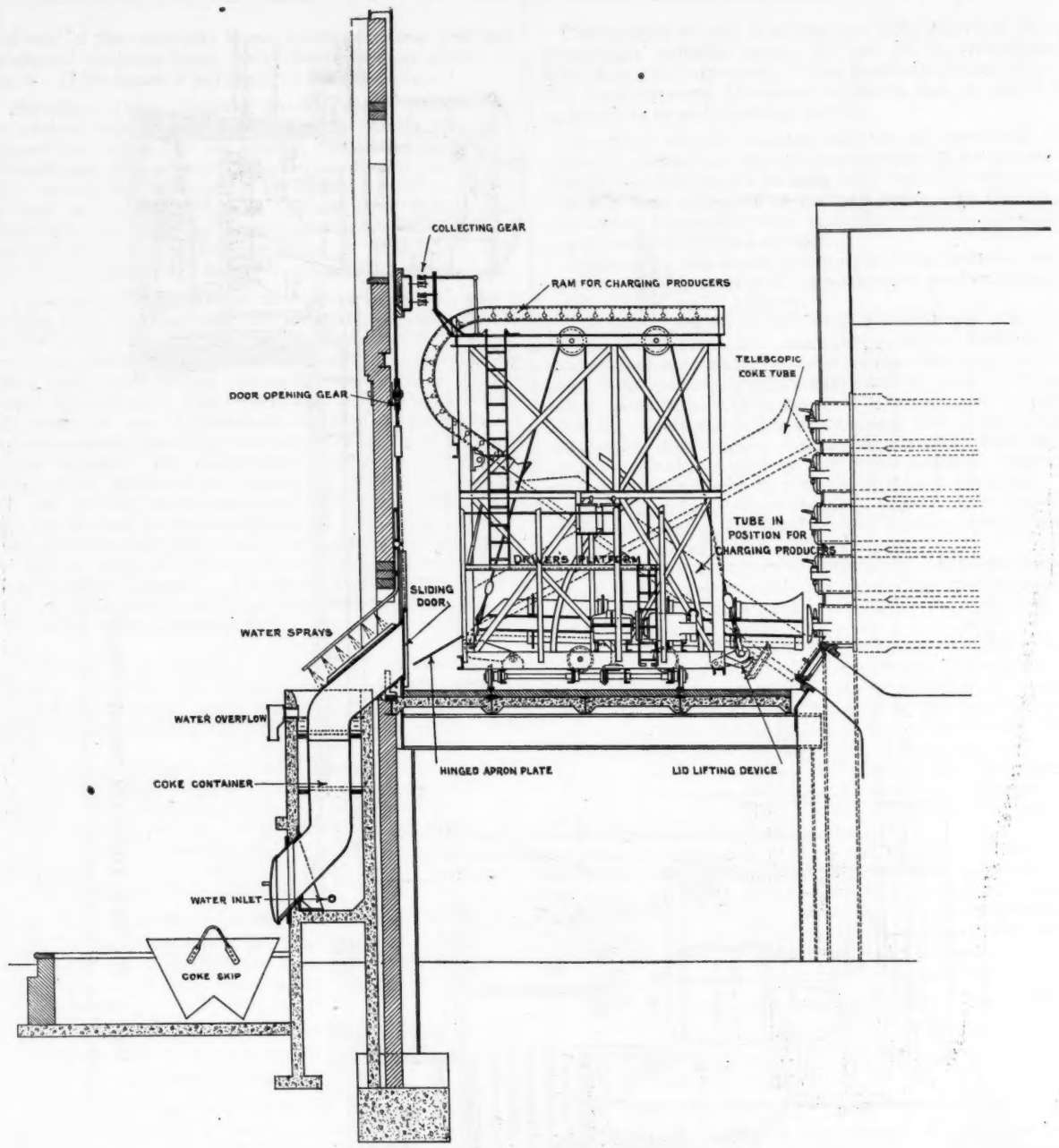


Fig. 4.—"G.N." HOT COKE HANDLING MACHINE AND PRODUCER CHARGER IN CONJUNCTION WITH A COKE DRY-COOLING PLANT.

In this estimate no credit is given for reduction of labour or for recovery of waste heat, which in a large installation would be considerable.

If this matter be considered from the point of view of the consumer, the difference in value between moist coke and dry coke will be as shown below:

	20 p.c. moisture.		10 p.c. moisture.	
	s.	d.	s.	d.
Cost of one ton of moist coke at works ...	32	6	32	6
Cost of carriage to consumer's premises...	5	0	5	0
	37	6	37	6
The relative value of dry coke to the consumer would be...	48	2	42	2
Increase in value to consumer	10	8	4	8

Relative Fuel Values.

Coke 20 p.c. moisture	77·8
Coke 10 p.c. ,, ...	88·9
Coke, absolutely dry	100·0

If the consumer now pays 37s. 6d. per ton delivered for coke containing 20 p.c. of moisture, he could afford to pay 10s. 8d. per ton more for the dry coke, without incurring any loss in fuel value.

From the point of view of the gas undertaking, however, the position is somewhat different, as will be seen from the following statement:

When the gas undertaking sells one ton of moist coke containing 20 p.c. moisture, it really receives 32s. 6d. for 0·8 ton of coke, or, in the case of coke containing 10 p.c., for 0·9 ton.

These prices are equivalent to 40s. 7½d. and 36s. 1d. respectively per ton of dry coke, and to obtain the same return these prices would have to be obtained, plus the extra cost, if any, of producing the dry coke.

This latter item in a large installation would no doubt be more than covered by savings in labour and waste heat recovery.

It will be seen, therefore, that the consumer would be 2s. 6½d. to the good if he paid 8s. 1½d. more for dry coke than for coke containing 20 p.c. moisture, while he would be 1s. 1d. to the good if he paid 3s. 7d. more for dry coke than for coke containing 10 p.c. of moisture.

It may be said therefore that the production and sale of

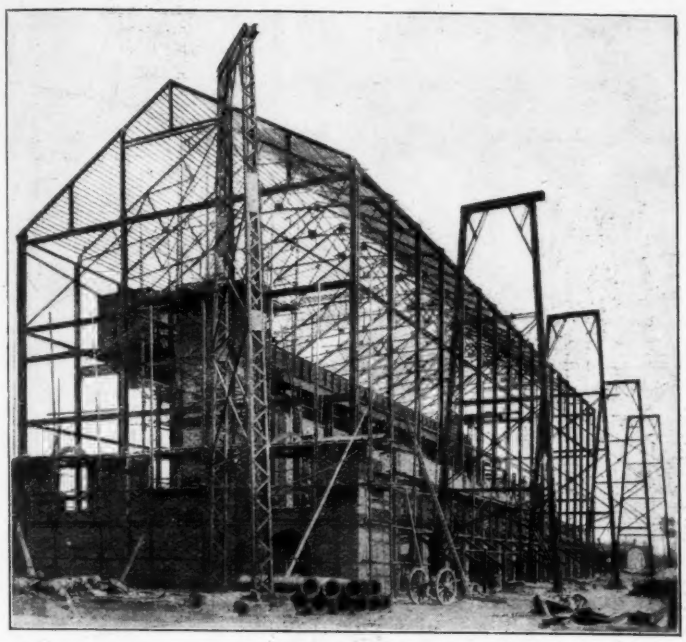


FIG. 5.—THE RETORT-HOUSE UNDER CONSTRUCTION.

coke in an absolutely dry state is a sound proposition, provided that the customer is made to appreciate the superior value of the dry fuel.

Coal-Handling Plant.—For convenience in handling the coal delivered by rail, new sidings were laid down near the retort-house, and a rotary wagon-tippler electrically operated, including electric clamping gear, was provided, with a weighbridge alongside. The existing works sidings were renewed and extended to accommodate full train loads of coal and deal with the wagons expeditiously.

The tippler is capable of discharging at the rate of one wagon every four minutes, including the time taken in moving the wagon in and out of the tippler.

The two coal breakers, in a pit below the tippler, are of very strong construction, each capable of breaking hard cannel to a size of about 1¼ in. cubes at the rate of 40 tons per hour. They are provided with jigger feeds.

It may be of interest to mention that the contractors had considerable difficulty in complying with the specification as regards the size and rate per hour; the breaking of cannel being a much more difficult matter than the crushing of coal. It was only after many alterations and experiments had been made, extending over two years, that the conditions of the specification were fulfilled.

The coal is carried from the coal breakers to the top of the retort-house at the middle of the building by means of a gravity bucket elevator and conveyor of 40 tons capacity. The elevator and conveyor will be altered (see fig. 3) and duplicated when the other retort-house is constructed. From the middle of the house the coal is conveyed in either direction by means of tipping tray conveyors to the coal bunkers, which are large enough to contain two days' requirements. The general arrangement of the coal handling plant may be seen in fig. 3.

Conveyance of Coke.—Consideration was given to the possibility of carrying the red-hot coke direct from retort to water-gas generator. The conditions, however, were not favourable, as the quantity of coke needed by the generators varies greatly, and, moreover, the destructive action of the red-hot coke on the skips, shoots, etc., would have meant heavy charges for repairs.

The system eventually adopted was an installation of electric telpherage, whereby the coke is elevated in skips and run over hoppers fixed in the roof of the generator house, from which the coke can be taken, screened, and deposited in the generators by gravity. (See fig. 7.) The skips are of 25 cwts. capacity, and are provided with bottom opening doors to reduce the fall to a minimum.

The first section of the track is 608 ft. long. When the second retort-house is built, the full circuit will be completed, and the total length will be about 1400 ft. The shoots leading from the hoppers to the generators are provided with cascade screens, which are very efficient in taking out the fine breeze.

Condensers.—The gas, after leaving the hydraulic mains, passes round the retort-house from each bench separately in 18 in. diameter steel mains, each about 550 ft. long. The cooling is completed by two batteries of water-tube condensers. By this means a more effective control of the temperature can be effected in warm weather than by means of the atmospheric condenser.

The exhausters of the Donkin four-blade type, the power generating plant, the rotary washer scrubbers, and the Livesey washer do not call for special comment.

Provision has been made in the connecting mains for the erection of washers for the extraction of cyanogen, if desired, at some future time.

Purifiers.—The question as to whether the construction of the purifiers should be in concrete or cast iron was carefully considered, and designs were prepared in both ways. Owing to the high price of cement at the time, the cost of construction in concrete was not much less than that of cast iron. So small was the difference that the preference was given to cast iron, having regard to the fact that experience with concrete purifiers did not extend over any great length of time, whereas cast iron was a well tried and thoroughly reliable material for the purpose, and would give greater confidence as to life, durability, &c.

The purifying house is of the open-shed type with revivifying floor at ground level, the purifiers being supported on a number of blue-brick piers built in cement, and the roof being supported by steel stanchions from the top of the purifiers.

A gravity-bucket conveyor was provided for handling the purifying material, the lower part running a few inches above the ground floor, and provided with wooden guards which also serve the purpose of guiding the oxide into the buckets. The upper part of the conveyor runs under the centre bay of the roof, and is provided with suitable tipping gear and shoots for charging the boxes, a special wooden shoot being provided for delivering oxide to the disintegrator.

To avoid corrosion and extend the life of the conveyor buckets, a trial has been made with buckets coated with vitreous enamel. This adds about 50 p.ct. to the cost of the buckets, but it is believed that the life will be increased at least fourfold.

The disintegrator is fixed under the purifiers at the extreme end of the house, and is capable of grinding to a fine state 16 tons of oxide per hour. It is fed by the gravity bucket conveyor already mentioned. The material, after being ground, is taken away from the outlet shoot under the machine by means of tip wagons, in which it is brought alongside the conveyor in readiness for recharging the purifiers. The material in passing through the machine is thoroughly revivified and practically ready for re-use immediately. The cost of preparing the oxide by means of the disintegrator is about one-fifth of the cost of doing the same work by the old method of hand labour.

It may be of interest to mention the method used at Garston for dealing with the gas in the purifier before the lids are lifted for changing. This method has been successfully in use at Liverpool for the last twenty years.

Each of the purifiers is connected to the inlet of exhausters by a system of pipes and valves through which the enclosed gas under pressure may get away without being blown into the atmosphere, thus largely minimizing the nuisance caused by the smell of foul gas when the purifier is opened.

After the purifier has been re-charged with oxide and the covers replaced, clean gas is drawn through the box from an adjacent purifier by the exhauster, using the same connection; the air being subsequently passed on to the other boxes, where it assists in revivification *in situ*.

The purifiers are operated by a 24 in. Weck centre valve in the usual way.

Naphthalene Washer.—This washer of the horizontal rotary type was erected in the summer of 1923 by Messrs. W. C. Holmes & Co., Ltd., on the outlet of the purifiers. It has been working continuously since last August (1923) with gas oil as the washing medium, and the entire removal

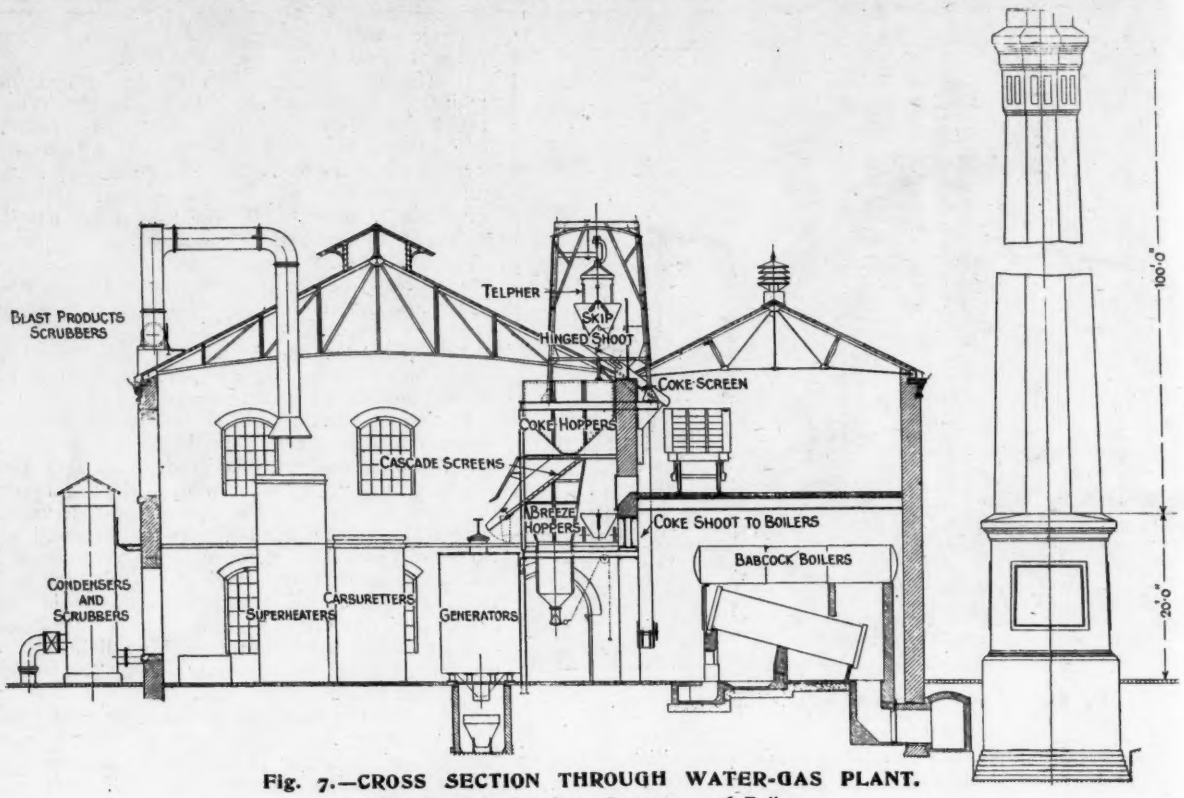


Fig. 7.—CROSS SECTION THROUGH WATER-GAS PLANT.
Showing Coke Supply to Generators and Boilers.

of naphthalene has been effected by using 16 gallons of oil per million c.ft. of gas treated.

The washer has the distinction of being the first Holmes washer in which the case has been constructed of mild steel, with welded joints. This method of construction has certain advantages over cast iron ; it is lighter in weight and less in first cost. The engine is housed in a circular extension of the washer itself, constructed in mild steel, and suitably ventilated so that no further protection is necessary. (See fig. 9.)

The only objection to this form of construction that can be seen so far is that mild steel is more liable to external corrosion, but this need not cause any anxiety so long as painting is not neglected.

Station Meter.—The prohibitive cost of station meters of the ordinary wet type led to the consideration of the relative merits of other meters of the inferential type. At Linacre a rotary meter had been in use successfully for several years as an auxiliary to a larger ordinary wet station meter, the connections being so arranged that it could be used in series with the ordinary station meter during summer time, when the quantity of gas being made was sufficiently reduced.

It was found at Linacre that accurate results were obtainable when the rotary meter was run at or near its full rated capacity. Any variation in gas made was therefore taken up by the ordinary station meter, the rotary meter being kept somewhere near its proper capacity.

At Garston it was found possible to reproduce these conditions, as there was already an ordinary station meter of the wet type available. The rotary meter was therefore selected.

A certain amount of trouble was experienced at first, due to the deposition of naphthalene, but otherwise the meter has been working well.

Tar and Liquor Tanks.—The provision of adequate storage for tar and liquor was of special importance, as the Garston works are situated at considerable distance from the tar and sulphate of ammonia works.

It was decided to construct underground tanks of sufficient capacity to accommodate three to four weeks' production of the whole section when completed.

The relative merits of construction in concrete and in brick and puddle were considered. Notwithstanding the high price of cement, the cost of construction of the tank in concrete worked out somewhat cheaper than that of the brick and puddle tank, but the latter was adopted as being the more reliable. Similar brick tanks had been built at other works of the Company which had stood the test of time.

The capacities of the tar and liquor tanks up to the springing line of the arched roof are respectively 120,000 gallons and 295,000 gallons. The extreme length inside is 120 ft. 9 in., the width is 60 ft., and the depth to springing of arch is 11 ft. 3 in. The top is constructed of brick arches carried by the cross walls and the division walls of the tanks.

At each side of the tanks chambers have been built, into which the liquid products from the plant run, and are separated into tar and ammoniacal liquor. Suitable manholes with sealed cast-iron lids are provided for giving access to the tanks. (See fig. 8.)

Gasholder.—At the time of the erection of the new coal-gas works at Garston further storage accommodation for gas was not a pressing need, although for some time it had been evident that a second gasholder would be a great convenience, and would provide for much greater flexibility in working, seeing that coal gas from three town stations is mixed with the gas made at Garston.

It was decided at the time to postpone consideration of a new holder in the hope that prices would come down. Since then, however, the existing gasholder at Garston of four million cubic feet capacity has given trouble, the side sheeting having become distended to such an extent that the outside vertical stiffeners of the second lift are rubbing against the dip plates of the third lift, not in one place only but more or less all the way round the holder.

As the Garston works were entirely dependent upon the one holder, it became imperative that the construction of a second holder should be put in hand without further delay, to enable the existing holder to be thrown out of action for examination and repair. Referring to fig. 1, as already stated, the site (B) adjoining the present holder would accommodate a new gasholder of some five or six millions capacity. The land alongside Banks Road in a southerly direction had been also ear-marked to accommodate any further gasholders that might be required. It was found that this plot would provide space for three gasholders, two of them (D and E) of about 240 ft. diameter, and one smaller one (C) of about 150 ft. diameter.

While there was no immediately pressing call for additional storage capacity from the general point of view, the need that had arisen on account of the existing holder having developed trouble could only be met by the erection of a second holder. Moreover, there was the desire to avoid a large capital expenditure, such as would have been

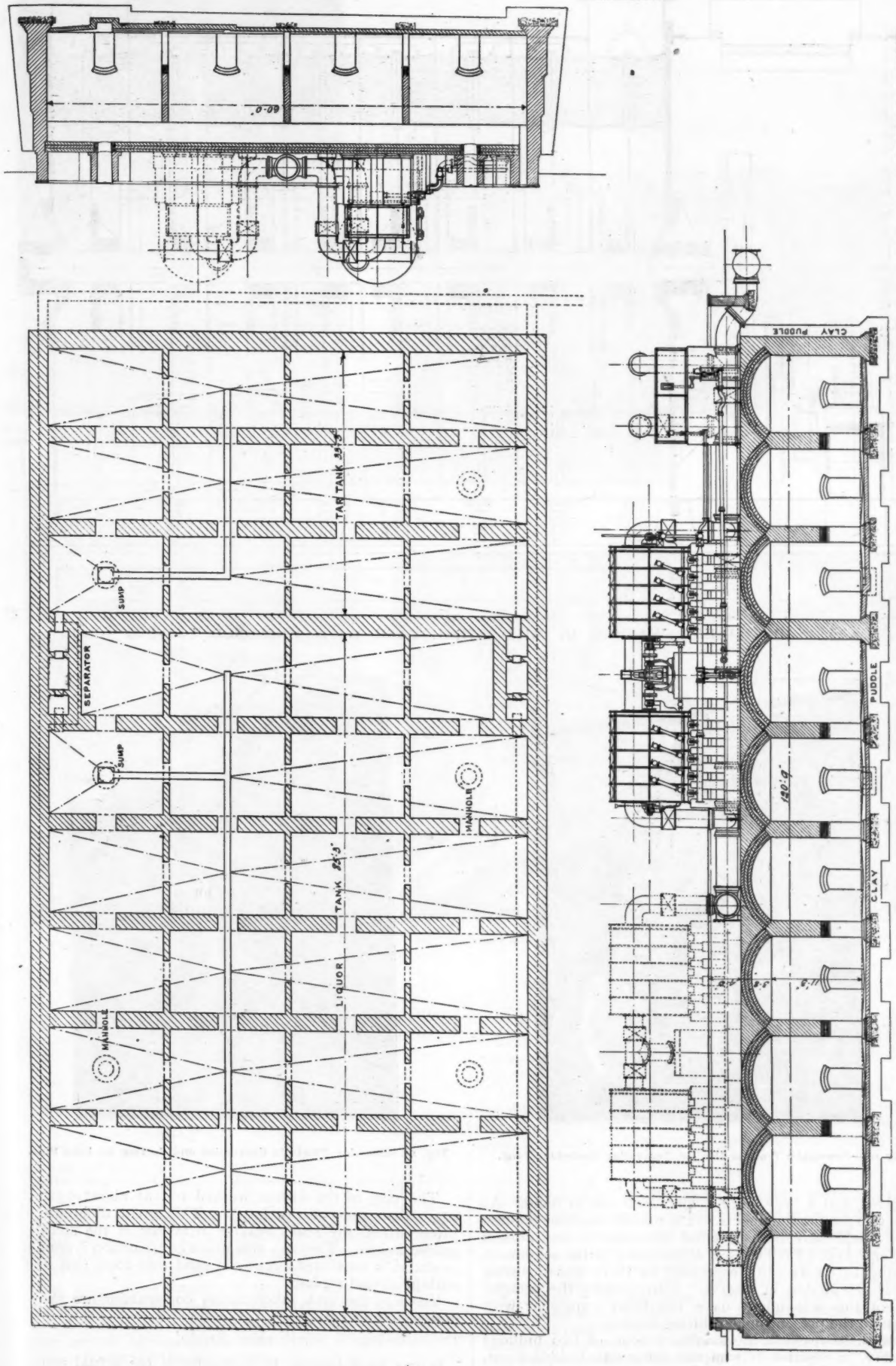


Fig. 8.—SECTIONS THROUGH UNDERGROUND TAR AND LIQUOR TANKS, SHOWING ARRANGEMENT OF WASHERS AND SCRUBBERS ABOVE.

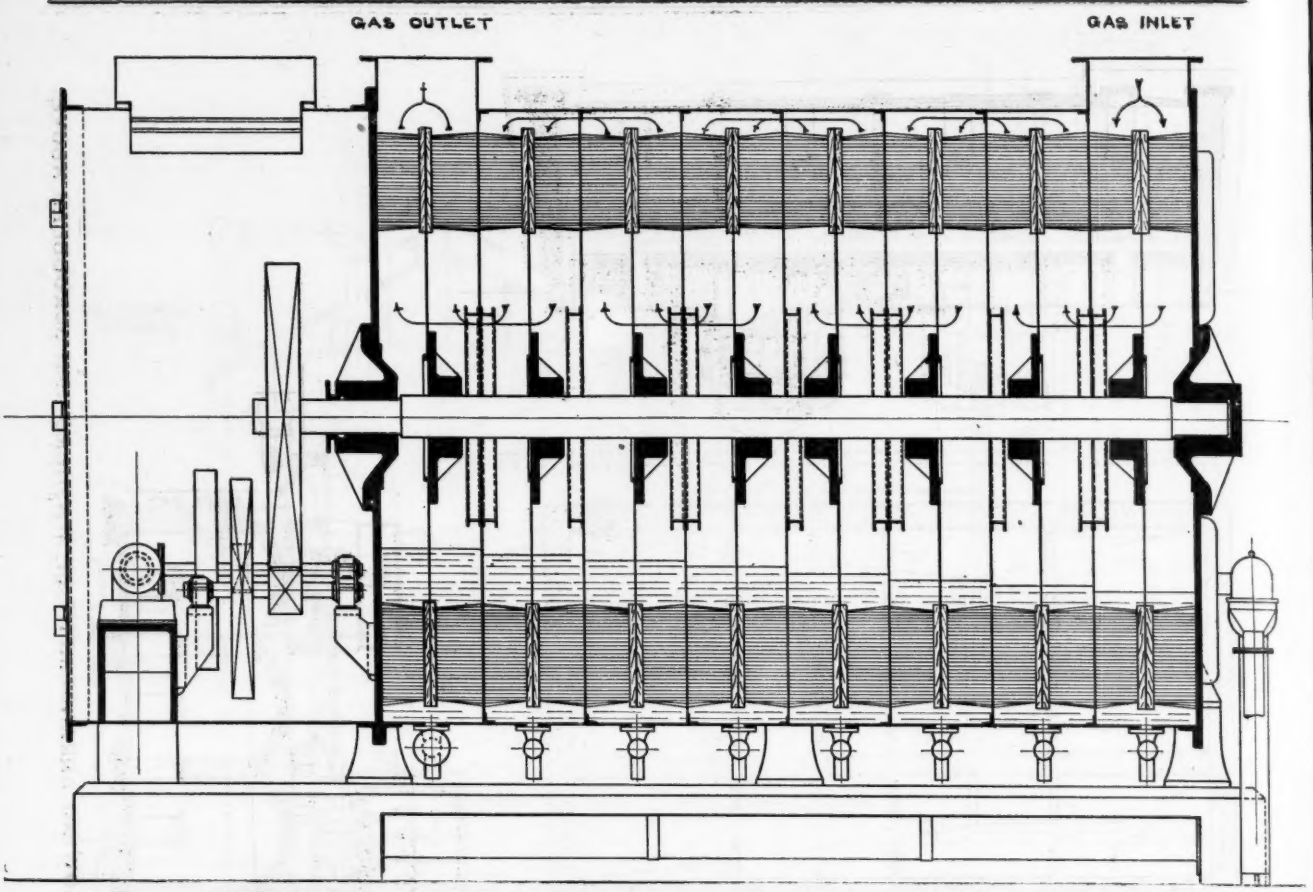


Fig. 9.—NAPHTHALENE WASHER IN MILD STEEL CASE WITH ENCLOSED DRIVING GEAR.

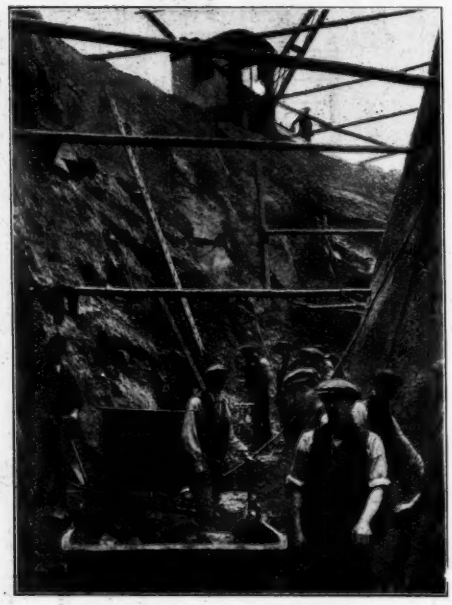


Fig 10.—Pneumatic Tools in Use for Excavating Gasholder Tank.

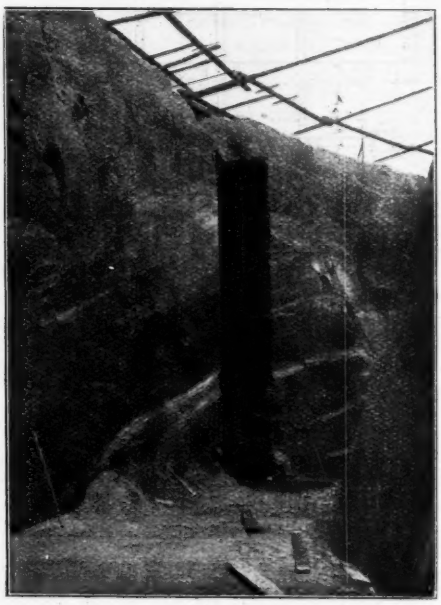


Fig. 11.—Showing Strata in Excavation and Cutting for Inlet Pipe.

involved had a very large holder been put in hand. An objection for the time being to the site (B) was that the new tank would have been in close proximity to the present one, and might have caused disturbance of its neighbour, a thing to be avoided, especially as there was no other holder at Garston in reserve. Furthermore, the occupation of this site might have interfered somewhat with access to the present holder during repairs.

For these reasons, the smaller holder, of two millions capacity, in position (C) on the plan, was decided upon. Drawings and specifications were prepared and tenders obtained for a holder with full guide framing, and alternatively a spirally-guided holder.

The cost of the former worked out at about 25 p.ct. more than that of the latter. This great difference in price turned the scale heavily in favour of the spirally-guided holder. The tank now under construction is annular in shape, is excavated out of soft sandstone rock, and lined with brick and asphalt.

Views of the tank taken during construction are shown in figs. 10 and 15.

Working Results.

It may be of interest to give some of the actual results obtained with the new plant:

Carbonizing Results.—(Without steaming).

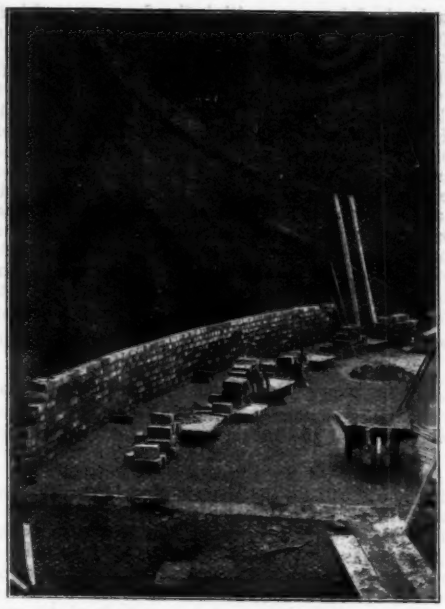


Fig. 12.—Outer Lining in Concrete and Brickwork at bottom of Tank.

Fig. 14.—Excavation for new Gasholder Tank.

Fig. 13.—Asphalt Lining on Outer Wall of Tank.

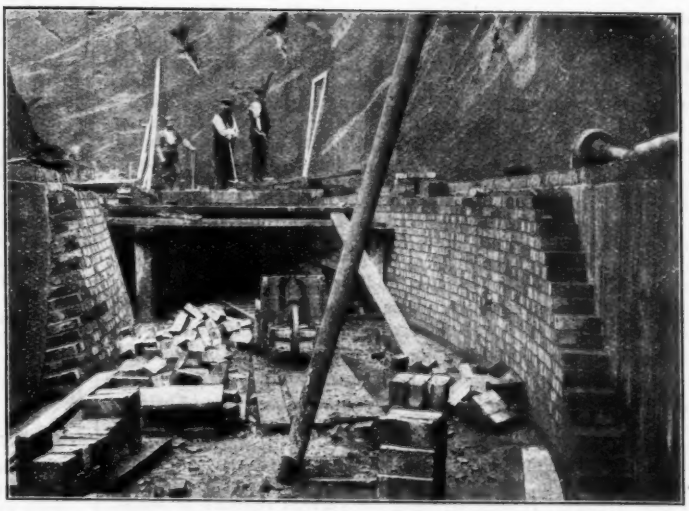


Fig. 15.—Inner and Outer Brickwork Lining of Tank with Asphalt between.

Period.	(A) One Month, Aug. 1 to 31, 1922.		(B) 18 Months, July 1, 1922, to Dec. 31, 1923.
Duration of charges	12 hours	...	12 hours
Description of coal carbonized :—	p.ct.		p.ct.
Arley Screened Coal...	16	...	5
Other Lancashire Screened Coal	44	...	53
South Yorkshire Screened Coal	40	...	35
Welbeck Cannel	—	...	7
Total	100		100
Gas made per ton	13,693 c.ft.	...	12,866 c.ft.
Calorific value	584·00 B.Th.U.	...	571·11 B.Th.U.
Therms per ton	79·97	...	73·48

Column (A) gives the results during the month of August, 1922, when an average of practically 80 therms per ton was maintained, and column (B) gives the average results over a long period of 18 months.

For about three months in the year the whole of the coke made at Garston (except that used in the furnaces) is converted into water-gas so that the total gas actually made per ton of coal during that period is approximately 34,000 c.ft., or 135 therms per ton.

Carbonizing Costs.—The carbonizing costs at Garston are lower than those for any other horizontal installation belonging to the Company, and are only slightly higher than the costs for the vertical installations at the Linacre and the Athol Street works.

It is expected that after the benches are reset with silica retorts it will be possible to carbonize 300 tons per day in three shifts of eight hours each, with further substantial reduction in working costs.

In conclusion, the author wishes to acknowledge his indebtedness to the members of his staff, and especially to Mr. Astbury, Mr. Fletcher, and Mr. Nicoll, for the assistance they have rendered in the preparation of this paper.

Discussion.

THE PRESIDENT: Mr. Gibson, in the opening paragraph, refers to the fact that the paper has been prepared at the request of the President. I did make such a request, and I ventured to press it as strongly as lay in my power. I am pleased that I succeeded in obtaining Mr. Gibson's willing consent to prepare and submit a paper on this subject. My object was a dual one, because I believe, first of all, that there is no type of paper which is of greater value to the members of the Institution than one which records the reasons, the conclusions, and the details of the engineering work involved in the lay-out of a large station such as that which Mr. Gibson has completed at Garston. While it is true that the capital costs are to-day no guide to the present costs of similar work, those who have had the pleasure of visiting Garston will know that it is an example of the highest art of the

engineer in its peculiar adaptability for its purpose, in the permanent character of the work, and in the economical cost. There is evidence of all these qualities in each section of the work. Taking such a view, I am sure we could not have anyone more able to present a paper with usefulness to the Institution than the author, for the thorough and painstaking character of his work is known to us all. I have therefore no regret at having put pressure on Mr. Gibson, and I know I shall be forgiven by the members for having exercised that privilege.

Mr. H. DAVIES (Chesterfield): I should like to express my appreciation of the paper and the information which it contains. There are one or two details to which I should like to refer. With regard to foundations, one notices that the author has steered clear of reinforced concrete on almost every occasion. I was wondering whether he has anything in his mind as to this matter, and if from his experience he can tell us whether he has any real objections to using reinforced concrete instead of mass concrete (say) 8 ft. thick, which forms the foundations in the retort bench. Also, the capacity of the plant is stated to be 2½ million c.ft. Is this the average or the maximum capacity? In regard to fuel consumption, he does not state this in the paper, and it would be interesting to know. I have had a great number of engineers to visit my works, where I have installed different types of inclined bar and other forms of grate furnace during the last few years, and they always ask me for this information, and I think we should be interested to have it for Garston, if the author can supply it. Referring to coke quenching, this is extremely interesting, and I congratulate the author on the results obtained. He has only installed this plant to deal with one bed. May I ask if it is his intention to extend it further? His confidence expressed thus would perhaps assist us in dealing with the matter ourselves. There is one other point; and that is in regard to coke values. We are unfortunately not in a position to make dry coke, but I should like to ask the author what is his experience in persuading the consumer to pay an extra 10s. 8d. per ton for dry coke compared with the coke made at his other works?

Mr. D. IRVING (Bristol): We are all greatly indebted to Mr. Gibson for his practical and well-reasoned paper. There is only one point to which I wish to call attention, and that is his comparison of coke values. I am sure we are all interested in hearing of the progress made in turning out dry coke, but however true—and I do not for a moment question the figures of the samples taken—it may be that the particular sample he took for comparison contained 20 p.ct. of moisture, I think it is most undesirable that it should go forth from this meeting that this is to be taken as anything like an average amount of moisture in ordinary gas coke. The idea that in every five tons of coke that you send out there is one ton of moisture is questionable, and I think it is not desirable that this should go forth from this meeting as being accepted as being anything like the average of the moisture in coke supplied by well-conducted undertakings.

Mr. J. P. LEATHER: Whether or not anyone here is likely to have to design new gas-works, we are much indebted to Mr. Gibson for the paper which he has presented to us. There is greater freedom in the design of an entirely new works, but the paper is nevertheless a guide to anyone who is trying to bring a works up to date. I have recently had to design an entirely new works, and I have been glad to visit Mr. Gibson's works and have the benefit of a conversation with him. There is only one point I shall touch upon, and this has already been referred to—the dry cooling of coke. Having decided for various reasons to adopt horizontal retorts in the new works I have referred to, the point which caused me most thought was the disposal of the hot coke. Anyone who has been in close proximity to a retort when red hot coke is being discharged must have been impressed with the large amount of heat wasted, and, further, when water is thrown upon it the resulting bad effects not only on the quality of the coke, but also on the atmosphere of the retort-house, resulting in corrosion of steelwork as well as insanitary conditions for the workmen. The coke may be removed from the retort-house before quenching by various methods with which most of us are familiar; and that which Mr. Gibson has designed is one of the best. At the same time, I think those who have this problem to consider should investigate the Sulzer process, which Mr. Gibson has mentioned. A visit to Holland to see the nearest plant which is in operation is no more travel than for members to come from the North of England to London to see a London works; and I was told when I was there (not very long ago) that I was then the only English engineer who had been to the Continent purposely to see the Sulzer process. Personally, I do not know of more than one other engineer who has been there, though others may have done so during the last few months. Whether Mr. Gibson has been I do not know, but it was largely Mr. Gibson's remarks to me which put me in the way of going. He mentions that the water leaving the cooling chambers may be used for boiler feed. With the Sulzer process, however, not only is a large quantity of water required, but it is all converted into superheated steam; and Mr. Gibson's cost of £600 for a plant only capable of dealing with 11½ tons of coke per day seems to me little difference, per ton of coke, than putting in a Sulzer plant, assuming a fair-sized plant is put in. The adoption of the Sulzer plant would obviate the necessity for installing any solid fuel steam boilers on the works at all, with a consequent saving in doing away with boiler firemen—and boiler firemen's wages for 24 hours a day add up to something. I am not wanting now to go into the Sulzer process, but merely to recommend members to investigate it. My own opinion after doing so was such that I recommended it to my Committee for the new works I mentioned. The author has referred to the advantages of dry coke even at a higher price, with the proviso that the consumer is made to appreciate the superior value of this particular fuel. There is no doubt that this proviso is an important one. People generally are going for the cheapest thing they can get, and do not always appreciate the advantages of paying more for a better quality. I would point out to Mr. Gibson—what he probably already knows—that where the coke is being used for the manufacture of carburetted water gas, you at once get all the benefit of the dry coke on your own works.

Mr. J. G. TOOMS (Christiania): I am engaged on the construction of a new retort-house in Christiania, and it may interest members if I give my views on one or two points arising out of this work and also the paper. I returned to Christiania ten days ago, after a tour of Germany and Austria; and without going into the merits and demerits of the Sulzer process for quenching or cooling coke, there is very little of this process to be seen in Germany or Austria. I think the economical consideration of the use of this plant will be the determining factor that will prevent its extensive adoption. I saw a plant in Mannheim in connection with Dessau vertical retorts handling (if I remember rightly) about 1000 tons a day, and utilizing the calorific value of the heated coke for the production of steam. They did not know what they were going to do with any more steam; in fact, at Mannheim they have difficulty, at certain periods of the year, in utilizing all the steam they produce. So far as I know, the waste gases from their retort bench were coming off at about 600° C., so with this coke cooling process, I do not think that in many cases one can put on the credit side the value of the steam that you are going to obtain. In the early part of the paper, the author states: "Coal-gas plant with horizontal retorts fulfilled the conditions, and had further advantages when compared with the vertical system as regards lower capital costs, greater ease of control, and wider choice of coals, while greater freedom was secured in obtaining tenders." There is one point there with which I venture to say a good many of his colleagues will not be in agreement, and that is the greater ease of control. It is an important question, but the point I want to raise is one of extreme interest to the gas industry—viz., with regard to nuisance created by gas-works. My Directors, on my advice, have decided not to entertain any other system than the continuous vertical retort, irrespective of whether horizontals will give more therms per ton of coal, and irrespective of the economical results, because where these retort houses are put up in the midst of a high-class residential district or a residential district at all, any fumes or smell or other nuisance will make itself felt over a very wide area, and over a very large number of people. I venture to suggest that this is a most important point for the future of the industry—viz., so to arrange our works and operations—and I am pleased to see that Mr. Gibson is doing what he can to reduce the nuisance from his purifiers—that they do not constitute a nuisance to the neighbourhood. I want to make this point because I think the industry will be well served by paying greater attention to this matter.

Mr. W. S. MORLAND (Gloucester): I have listened with much interest to Mr. Gibson's paper, and especially to the results of his work with the dry coke. I know from experience that where you are working coke containing a considerable amount of moisture, if you are using it for making carburetted water gas the output per ton of coke used is considerably reduced. Of course, it is not always convenient to make this dry coke in a gas-works; and it has occurred to me that if we are going to adopt this method of cooling our coke, our expenditure will not stop at the cooling plant. As we know perfectly well, at times we have to store our coke; and if we are going to take all this trouble to secure absolutely dry coke, then it is up to us as an industry to cover-in all our coke yards. This is a point we must not lose sight of—viz., that having reduced the quantity of moisture in the coke, we must see to it that it is kept in that dry state until it is sold. I believe that some years ago Mr. Allen, at Liverpool, had a demand for dry coke in the making of biscuits. I think he told me that this was the reason he first went in for making dry coke, but it does not appear to me to be at the present time a product which many works will adopt generally. The capital expenditure would be considerable. Another thing which interested me is that during the war period, when iron was an enormous price, many people went in for the construction of concrete purifiers. I suppose they are more difficult to keep tight, but, apart from this, I have always held the opinion that a purifier will not last for ever. Some time or other they will become too small, or you will have to take them down for other reasons; and I can see a big cost in breaking up concrete purifiers which would be no good to you at all afterwards as compared with iron purifiers. There were some concrete ships built during the war, and some of them were constructed outside our works. One of them was launched, but unfortunately in launching it broke up, and it cost more to break it to pieces to clear the fairway than it had cost to build. Anyone thinking of concrete purifiers should consider the matter carefully. I think Mr. Gibson has adopted a wise course.

Mr. T. F. E. RHEAD (Birmingham): I have not had much time to go into the paper, but I should like to know if the author's retorts are silica or fireclay. I should also like to know the temperatures at which he works them. It is extremely interesting to see that he has obtained 80 therms per ton in a month's run. To me, this is an abnormally high result. I think the richest coal I have tested gave barely 80 therms per ton. It is also noticeable that with a cannel coal over a period of 18 months' running, the average is considerably less than this. If the author could give the composition of his gas, stating the inerts, it would be extremely useful. I should like to feel perfectly sure that his rotary meter, with which he admits he had trouble, was perfectly correct during these tests. I have had experience of rotary meters, and under certain conditions they are reliable, but at times they are apt to be extremely misleading. I agree with previous speakers that 20 p.ct. of moisture in coke is a high average figure. Of course, the great trouble with horizontal coke is the variation in moisture content, but I should think the average content would be about 10 p.ct. I am glad to see that the author has gone in for keeping his coke dry and not wetting it, because I think it is a matter of good business. We have a duty to our customers; and by selling them dry coke—taking the long view—they will have a better opinion of horizontal coke than they have at present. Our experience in Birmingham with vertical coke, where the moisture is probably not more than 3 p.ct., is that they prefer that coke to any other.

Mr. W. CLARK JACKSON (Neath): I also wish to say something about coke, which has been referred to so often this morning. We have had to conform to a standard for tar, and we are also being urged to conform to a standard for sulphate of ammonia, and there is no reason why there should not be a standard for coke. I have two works, one of which has vertical retorts and the other ordinary hand-fired horizontal retorts. My largest consumer for coke is a large galvanizing works. This is a good customer, but during the past winter we experienced (as most of us did throughout the country) a shortage of coke, and we could not get out sufficient from the vertical retorts for this customer's requirements. Therefore I had to supplement the vertical-retort coke with some from the hand-fired horizontal retorts; but this was the cause of considerable trouble to me. I was rung up within 24 hours as to why this coke was different from the usual coke. The fact is that people who are working with coke immediately notice the difference if the quality varies. If a coke containing 10 or 15 p.ct. of moisture is sent to them, they at once find a difficulty in keeping up their temperatures. This all shows that we should pay a little more attention than has been done in the past to this matter. So far as my vertical coke is concerned, I have no difficulty in disposing of it, but I have difficulty in getting rid of my horizontal coke.

Mr. G. M. GILL (London): The author speaks of very high percentages of moisture in coke, and it seems to me that there is an idea in some people's minds that you cannot reduce the percentage of moisture in coke below a relatively high figure without expensive apparatus. I had an experience some years ago in seeing what could be done to reduce the moisture in coke by quite ordinary means, without having to go to the length of putting in anything such as a Sulzer plant. This coke was simply pushed out of the retorts and quenched with a hose pipe; and I found that with care and a certain amount of supervision, it was possible to reduce the moisture in that coke consistently below about 4 p.ct., with an average of between 2 and 3 p.ct. Careful samples were taken every day of the day's production at each works. I think that any engineer who wants to reduce the moisture in his coke and considers it necessary—as I do myself—will find it possible by ordinary means to carry this out. I can also say that you get back the value of doing this in your revenue account because of the increased demand from the consumers.

Dr. PARKER: I should be glad if the author, in replying to the discussion, would tell us something as to the amount of heat which is added to the water circulated through the water cooling chambers. A number of figures have been given in the past as to how much pre-heating of water can be obtained and how much steam can be raised by different systems, and it would be interesting to have some figures from Mr. Gibson regarding the method he is using and the amount of heat that is added to the water during the cooling of the coke. There is one other point which has already been mentioned by Mr. Rhead, and that is in connection with the measurement of gas by means of a rotary meter. In connection with the Gas Investigation Committee's Reports we have had a fair amount of experience with the use of rotary meters, and our experience has been this—that, with a perfectly clean gas, rotary meters are extremely reliable, much more reliable than I should ever have anticipated. In fact, there is less variation in the record with the rotary meter than with the ordinary wet meter; but there is just this condition, the gas must be perfectly clean. This was one experience. We also had another experience in which trouble was caused by the deposition of fine dust, and in that case our experience was different. The trouble that was caused may be illustrated by this example. We will suppose for a moment that the tubes in a rotary meter are 4 in. in diameter (the tubes leading to the vanes) whether they be of square or round section. This is a big size, but a deposit of only one-tenth of an inch of naphthalene or any other material on the inner wall of the tube will cause the meter to read 10 p.ct. fast. A deposit of one-tenth of an inch in a 4-in. tube will reduce the radius to 19-20ths in., which is 5 p.ct. less, and the speeding-up of the meter is approximately double the percentage reduction in diameter—*i.e.*, the readings will be 10 p.ct. too high. In our case we found it necessary to clean out the meter once a week. That was an extraordinary example, because we were dealing with an unpurified gas. I wonder whether the author has gone into this matter and found what percentage of speeding-up he had during the trouble with naphthalene.

Mr. W. H. JOHNS (Swansea): I should like to take this opportunity of thanking Mr. Gibson for his paper, and also for the great assistance he gave me in connection with the construction of our new works at Swansea. After considering the matter carefully, we have decided on horizontal retorts, incorporating in our scheme the "G.N." machine in use in Liverpool, which we think will be the means of overcoming many of the difficulties that have been referred to in connection with the quenching of coke. I am not going to inflict any further coke questions on the meeting. I should like to say, however, that we in Swansea have not overlooked the advantages claimed for the Sulzer process; but inasmuch as we are going on to an entirely new site, we have decided for the time being to adopt the ordinary water-tube boiler, and our scheme has been arranged in such a way that we can adopt the Sulzer plant at a later date. We have made up our minds about that, and we feel that the Sulzer system will receive great consideration in this country in the near future. Unfortunately, I have not had the pleasure (as Mr. Leather has) of going to Holland to see the plant, though it was my intention to go there; but we have, as a matter of fact, arranged for that plant to be installed at a later date. The reasons why we have chosen horizontal retorts at Swansea are the same as those given by Mr. Gibson. We make a large quantity of carburetted water gas, and feel there may possibly be some restriction on the CO content in the future. We wish to be on the safe side, and feel we can safely make gas with the percentage of CO allowed. I should very much like to know from Mr. Gibson what is his cost per therm into the holder. He may, perhaps, have some reason for not stating this publicly, but he may be able to give it to me privately. I think it will be a figure which will surprise a good many of us. In Swansea we have decided to go in for silica segmental retorts, after my experience of these in Sheffield, where their life has been from 10 to 12 years, with very small repairs and without damage to the ironwork and retort benches. I felt that as I have been responsible for the design of a gas-works of a similar or somewhat larger capacity to that of Mr. Gibson, it would be interesting to bring these facts before you. His works have a capacity of 2½ million c.ft., whereas mine have a capacity of 3 million c.ft. at the present time and probably 1½ million c.ft. of water gas. I wish again to thank Mr. Gibson for his paper and for the great assistance he has been to me in connection with the works I am just about to bring into operation.

Mr. W. G. S. CRANMER (Willenhall): Mr. Johns said he would not inflict any more coke questions on you, but I am going to do so. I have always been an advocate of dry coke, but I do not see that it is necessary to go to the expense of putting down special plant for attaining that object, because, as Mr. Morland has pointed out, whatever you may do in that direction may be neutralized by the effects of the weather, especially in such a season as we have had during the first few months of this year. I work horizontal retorts, and we quench the coke in a quenching tank. The coke, when it is tipped on the heap, as a rule turns out with a core of only partly quenched coke, with sufficient heat left in it to drive off practically the whole of the moisture left in the outside of the skip of coke, and eventually there is practically no moisture left in the coke. I cannot give you actual figures, but the coke is, to all intents and purposes, as dry as you can possibly get it without going in for the elaborate arrangements such as the author has described. One speaker referred to the value of horizontal coke compared with vertical coke, and he also mentioned that he had hand-fired horizontal retorts. It is there, I think, that he will find an explanation of his difficulty. The coke from machine-charged retorts using heavy charges is entirely different from that from hand-fired retorts, especially if it is a poor coking coal. My experience is that I have neighbours who produce nearly all vertical coke, but I can sell my horizontal coke against their vertical coke. My horizontal coke is going to the neighbouring towns simply because the people will not have vertical coke; the horizontal suits their purpose better.

Mr. GIBSON replying to the discussion said: May I first say that I am much gratified with the discussion that has taken place. I will do my best to reply to the points that have been raised; but they are so numerous that you must excuse me if I miss some of them or reply to some of them later. I am much obliged for the President's kind words, and appreciate them very much. Mr. Davies raised the question of foundations and wanted to know why we did not use reinforced concrete foundations instead of mass concrete. He spoke of the foundations as being 8 ft. thick, but that is not quite correct. I never said they were solid 8 ft. thick, but they go down to a depth of 8 ft. below the datum.

There was nothing to be gained by using reinforced concrete for this particular job. With regard to the capacity of the plant, 2½ million c.ft. is the nominal figure, but I expect that the plant will do well over 3 millions under the best conditions. With regard to the fuel consumption, I am sorry I have not any figures with me; but I believe they are good, and I can give them later if desired. Mr. Davies also asked whether, having regard to the experience we have had with the coke cooling arrangements on one bed, we would be prepared to extend them further. The other part of the installation is provided with an inclined quenching bench which has cost a considerable amount of money to put up. We do not intend to scrap that, but when it becomes worn out, or if we extend when we put the second installation in, we may go in for the dry cooling in connection with the extension. The matter, of course, has not yet been considered. With regard to the value of the dry coke and persuading consumers to take it at a higher price, I may say that we use the whole of this dry coke in our own water-gas plant and obtain the full benefit of it ourselves. We do not sell any. I might just remark that when we were making dry coke at Linacre some years ago, we had no difficulty in obtaining a higher price for it. The bakers and others who used it were much impressed with the superior quality. The appearance of it is wonderful. It is of a beautiful silvery grey colour, and appearance certainly goes a long way in inducing customers to pay a higher price. Mr. Irving expressed surprise that 20 p.ct. of moisture in the coke should be mentioned in the paper. The figures given in the paper were of course only hypothetical, and I did not intend them to be taken as actual, but merely for illustrative purposes. At the same time, I have seen analyses of coke which have been surprising as regards the moisture content; and I think if the members present will take the trouble to find out what moisture there is in their coke, some of them may have a rude shock. With regard to Mr. Leather's remarks, he has decided to go over to the Sulzer process. This process has a great deal to commend it, and personally I have formed a very high opinion of it. I have not seen the plant yet, but I hope to do so in the near future. It is, however, still more or less in the experimental stage, and for my own part I would rather like to see how Mr. Leather gets on with his plant before I go in for it. With regard to boiler feed, the water used in cooling is far more than is necessary for feeding the boilers at Garston, but we use excess for quenching the coke in the other part of the plant. As to the capital expenditure, Mr. Leather thinks that the £600 mentioned in the paper would come to as much as the Sulzer plant. I have not seen any quotations for the latter so I cannot say; but it does appear to me that the Sulzer plant must be more expensive than the one we have at Garston. I have already mentioned that the coke is used entirely on our water-gas plant, and therefore we do not need to persuade our customers as to the better value of the dry coke. I am much interested in Mr. Tooms' remarks, which were mainly on the point of nuisance. There is no doubt that the more we can do in the way of reducing nuisance from gas-works, the better we shall be liked by our neighbours. Mr. Morland referred to the reduced output from the water-gas plant where moist coke is used. This is so; and I believe there is a bigger carbonic acid content and, of course, a bigger expenditure of fuel. With regard to stocking, each engineer must consider this problem for himself. The great percentage of coke that is made is sold almost immediately it is produced, and it is only a small surplus that really goes into stock. With regard to concrete purifiers, I think where there is a considerable saving to be made by using concrete there will be a good case for construction in that material, but (as I say in the paper) in our case we found the game was not worth the candle. Mr. Rhead asked whether the retorts were fireclay or silica. They are fireclay, but when they are next renewed we propose to put in silica retorts. I have not the figures as to temperature, but I should think the combustion chamber would be between 1350° and 1400° C. I agree that 80 therms per ton is a very high figure. It is an average over 18 months; frequently we went much higher, and, of course, we also went lower. It varied to some extent with the qualities of coal that were used at the time. I am sorry I have not the figures with me as to the composition of the gas, but I can give them later. With regard to the rotary meter, Mr. Rhead wanted to know whether the meter was correct when the naphthalene trouble showed itself. We found it was about 4 p ct. out, as compared with the station meter at that time. With regard to the percentage of moisture in ordinary coke, I have seen vertical coke containing 17 p.ct. of moisture. Mr. Rhead takes the figure of 3 p.ct. This is a very low figure, but I have no doubt it can be attained. Mr. Jackson mentioned the trouble he had had with a large consumer of coke when he supplied horizontal coke. I think he must have had a very bad sample of horizontal coke. We have customers who prefer horizontal coke to vertical coke; but, on the other hand, we have others who like vertical coke better. Mr. Gill pointed out that the percentage of moisture can be kept down by ordinary means of quenching with a hose pipe. I agree that if great care is taken it can be done, but we are up against the human element, and we know what men are. Unless there is some definite method of keeping the moisture down, I do not think that it is attainable on a big scale. Dr. Parker asked as to the amount of heat added to the water in the dry cooling of the coke. I am sorry I have not any figures with me with regard to this. As I have previously remarked, however, the water used in cooling is afterwards used in quenching the coke on the quenching bench in the ordinary way, and we shall have to go to the trouble of seeing to what extent we can make use of the heat in the water. I was much interested in his remarks with regard to rotary meters. We had much trouble when naphthalene deposits took place inside the meter; but so far as our tests go, we have run the meter in series with the station meter of the ordinary type, and we found that when running at full capacity it is practically the same, or near enough for our purpose. I was much interested in Mr. Johns' remarks. The reasons which led us to adopt the plant we have at Garston have also weighed in his case, and I am interested to hear his comments with regard to the Sulzer plant. Perhaps he will be one of the first to be brave enough to adopt it. I am sorry I have not got the cost per therm into the holder, but I will give it later to Mr. Johns. I agree with his remarks as to silica segmental retorts, and think he is wise in adopting that material for his retorts. We are now proceeding with the installation of silica segmental retorts, having a setting working since 1918 at Linacre, the results of which show that the retorts are practically in as good condition now as when they were first put in. Mr. Cranmer believes in horizontal retort coke, and does not think that any special plant is required. I think I have dealt with that point already. On a small works I dare say greater attention can be given to quenching in the ordinary way; but on a large works it is not so easily accomplished.

PERSONAL.

As indicating the value which the Belfast Corporation place upon the services of Mr. J. D. SMITH, their Gas Engineer and Manager, the Council in Committee last Friday advanced his salary from £2000 to £2500, and in addition he enjoys a free residence. Mr. Smith recently presented a report of the undertaking, which showed that the concern was never in a more flourishing condition. The present increase makes him the highest paid official in the service of the Corporation. Previously that distinction was enjoyed by the Town Clerk.

Mr. B. N. DEY, B.Sc., A.M.I.Mech.E., is the first consulting engineer to obtain the high distinction of D.Sc. (Eng.) of Glasgow University, on his thesis on "Reinforced-Concrete Gas Purifiers and Other Gas-Works Structures."

Considerable interest was evinced at a wedding at Eastbourne on the 21st ult. The bride was the younger daughter of Mr. JAMES S. GARRARD, Secretary to the Eastbourne Gas Company, and the bridegroom was Mr. Charles Graham Henderson, of Clifton. A good many gas-men killed the proverbial "two bird's with one stone" by participating in the happy happenings and, incidentally, indulging in a very delightful week-end.

Friends will be pleased to hear that Mr. H. A. PACKHAM, son of Mr. H. W. Packham (Engineer and Manager to the Kingston-upon-Thames Gas Company) has passed the Maths. Tripos, Part I., and also passed Part II. Law Tripos, at Cambridge, with honours, and so qualified for the degrees of B.A. and LL.B.

OBITUARY.

As intimation of the sad occurrence only reached us at the moment of going to press, we are unable to do more now than announce the death at Bridge of Allan, on June 26, of a very old friend, Mr. JAMES WHIMSTER, late of Armagh.

The death took place last week of Mr. GEORGE KEMP, who retired several years ago from a responsible position with the Newcastle and Gateshead Gas Company, with whom he had been engaged for 53 years.

Mr. HUGH GOODWIN NEWTON, who died last Thursday at Chudleigh, South Devon, aged 51, had been a Director of the Imperial Continental Gas Association since 1906, when he succeeded his father, Mr. T. H. Goodwin Newton, who had been a member of the Board from 1867, and for eight years Chairman.

The death occurred at Hastings, on the 23rd ult., of Councillor GEORGE G. GRAY, LL.D., barrister-at-law, a Justice of the Peace for the borough of Hastings, and Chairman of the Hastings and St. Leonards Gas Company. For the last few months his health had been failing, and the end came very peacefully. He had reached his seventieth year, and it is said had crowded into his life more public service than any other man in the town. In fact, he entered the Town Council, of which he was one of the most prominent members, as long ago as 1897.

Compressed Air Caulking Machines.

Presenting to the Empire State Gas and Electric Association a report of the Committee on Labour-Saving Machinery in Distribution Work, Mr. J. K. Crowell, of the Westchester Lighting Company, said that, so far as he had been able to ascertain, there is no really satisfactory caulking machine on the market, for ordinary sizes of pipe. He had had some experience with one type of machine which was not at all encouraging. "If," he went on, "we could get a perfectly round bell and spigot, and get the spigot centred in the bell so as to give a joint space of exactly equal width all the way round the pipe, then the solution of the problem would be nearer. Perhaps centrifugally cast pipe would help."

THE VISIT TO PARIS.

CENTENARY OF GAS SUPPLY AND JUBILEE OF THE SOCIÉTÉ TECHNIQUE.

The Diary of a Memorable Occasion.

WITH the more serious part of the week's work left behind, it was an extremely cheerful party that began to assemble at Victoria Station at 3.15 p.m., on Thursday, June 26. The auspices were certainly good. One was conscious that another year of success had been registered by the Institution, and under a most popular Presidency; the time had arrived when the busiest quarter of the gas engineer's year had culminated in the high-pressure business of Institution week; and, perhaps above all, a most farcical imitation of summer had given way to blue skies and a sun obviously seeking to thaw ill feeling from his long-suffering subjects. And so it came about that 102 people met at Victoria, determined to have a very good time for the following four days.

M. FRANCIS ROULAND,
Président du Comité du Centenaire.

M. R. ELLISSEN,
Vice-Président du Comité du Centenaire.

LONDON TO PARIS.

The President and Mrs. Tagg were early on the scene, as was the President-Elect, accompanied by Mrs. Ferguson Bell and their daughter. Mr. and Mrs. W. E. Price had decided to add to many visits abroad, and Mr. and Mrs. Wilkinson to experience a further foretaste of the duties of the Chair. Mr. and Mrs. W. Doig Gibb, Mr. and Mrs. Thomas Hardie, and Mr. and Mrs. J. D. Smith were of the party, while Mr. A. E. Broadberry and Mr. Thomas Goulden had formed an advance guard to represent the Institution at the Congress, which opened earlier in the week. Though the fact may be taken as granted, it always gives us pleasure to record that Mr. Walter Dunn was doing his utmost to grease the wheels of organization and minister to the comfort of all. Has anyone ever paused to think how much organization is necessary for such an affair as this? Make the necessary pause, and then gauge the extent of the success which attended the meetings in Belfast and Paris—not a hitch; headquarters had done the thinking for everybody, and eliminated the possibility of muddle and inconvenience. This suggests a further point. One is rather inclined to fret at the idea of one's actual travelling and parts of the programme being confided to an agency; but with a great deal to be done in the time at disposal, it is an excellent thing not to have to decide whether to register luggage through, in which order to see the sights, and whether to pay at the desk or argue with the head waiter. And a qualified guide is much easier to get on with than a Baedeker.

A first-class Pullman on the road to Dover has a most stimulating influence (providing it is not winter, with an officially reported 30-mile wind); and the fact that near Folkestone a thick mist was encountered and that strangers only knew by instinct that the sea had been reached, had no damping effect upon the spirits. The mist hung low until near the French coast; but the train for Paris left not more than twenty minutes late. This was an advantage rather than a nuisance, for the trip on one of the fastest trains in the world was in the nature of an experience. It is quite usual for this train to do 125 kilometres per hour between Amiens and Paris; and last Thursday it arrived only 5 minutes late! Motor coaches were waiting at the Nord Station to take the parties to their respective hotels.

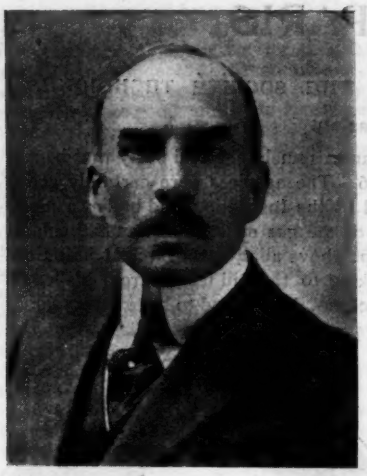
Friday, June 27.

AT THE ARC DE TRIOMPHE DE L'ETOILE.

It must be remembered that the ties which bind the Institution of Gas Engineers and the Société Technique are not really to be found in the round of pleasure, but in the pursuit of knowledge of gas engineering; and so it was fitting that Mr. Broadberry and Mr. Goulden should have attended the Congress from its opening, when a welcome was offered the delegates from abroad, to which Mr. Broadberry concisely replied for the British. Mr. Goulden himself presented a paper on "Recent Developments in English Gas-Making Practice," which we shall notice in an early issue. At the third session, on Friday morning, the President of the Institution was on the platform during the paper of M. Chappuis, and a number of other members were in attendance. A brief official welcome was accorded them.

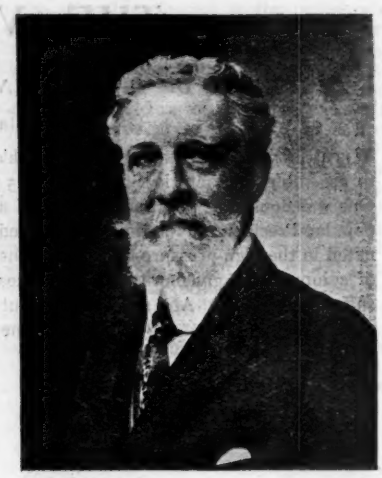
Shortly before 11 a.m., all those present proceeded in special tramcars to the Arc de Triomphe, where the other members of British and foreign delegations, with their ladies, and a number of the general public, had assembled to pay homage to France's illustrious dead.

The ceremony was both simple and impressive, as befits such an occasion. The Arc de Triomphe stands majestically over



M. L. ROLLAND d'ESTAPE,

Vice-Président.



M. RENE MASSE,

Vice-Président.

Paris, and yet the space around it is adequate; and the buildings which enclose that space of well-kept lawn, though large and stately, do not encroach upon the central feature. Approaching the Arc de Triomphe by the Champs Elysées, one has the impression that our Marble Arch would find accommodation beneath the French monument. Such is the shelter which has been chosen to cover the simple slab bearing the inscription:

Ici Repose un Soldat Inconnu
Mort pour la Patrie.
1914-1918.

By the head burns perpetually a flame, tended daily by one or other regiment stationed in the Metropolis; and there is a tablet to all foreigners who served France in her hourof need.

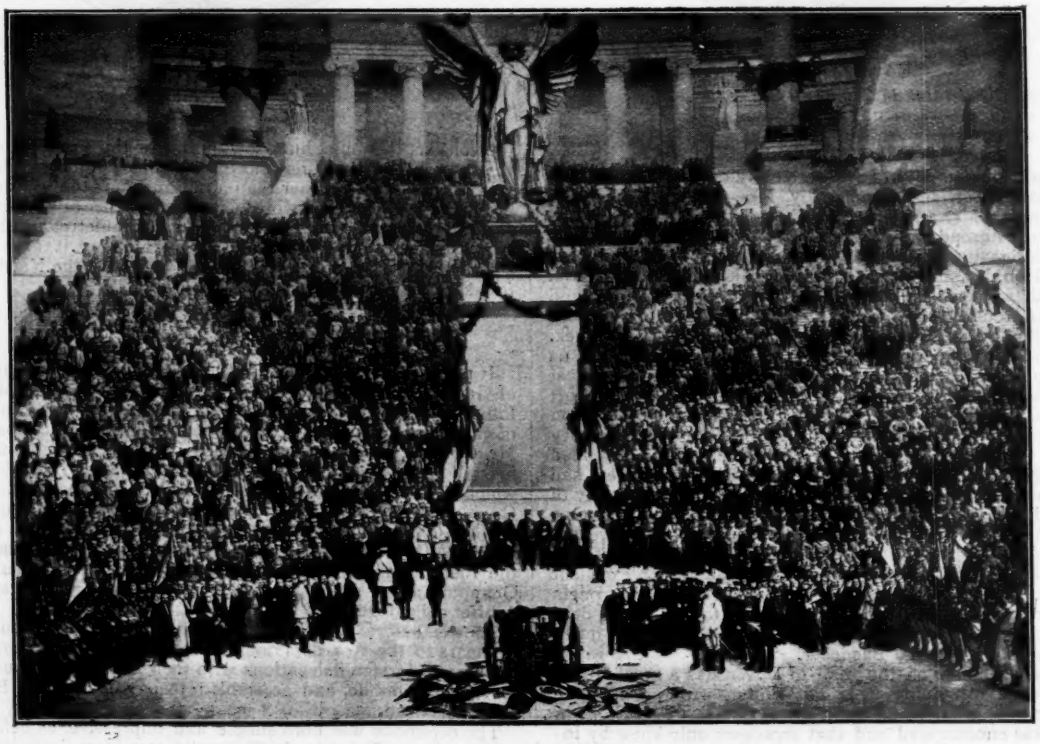
The various delegations were speedily marshalled together, and advanced uncovered to the tomb. When all had gathered round, the floral tributes—things of beauty in which roses of every shade predominated—were reverently placed, to join others among which was a wreath from King Carol of Roumania. Wreaths were laid, in addition to those from the Société Technique and the Institution, by the Italian, the Belgium, the Dutch, and the Spanish Gas Associations, and by the Board of the Prague Gas Company in Czecho-Slovakia. The photographs we reproduce are more eloquent of the ceremony than any written description.

The Real Paris.

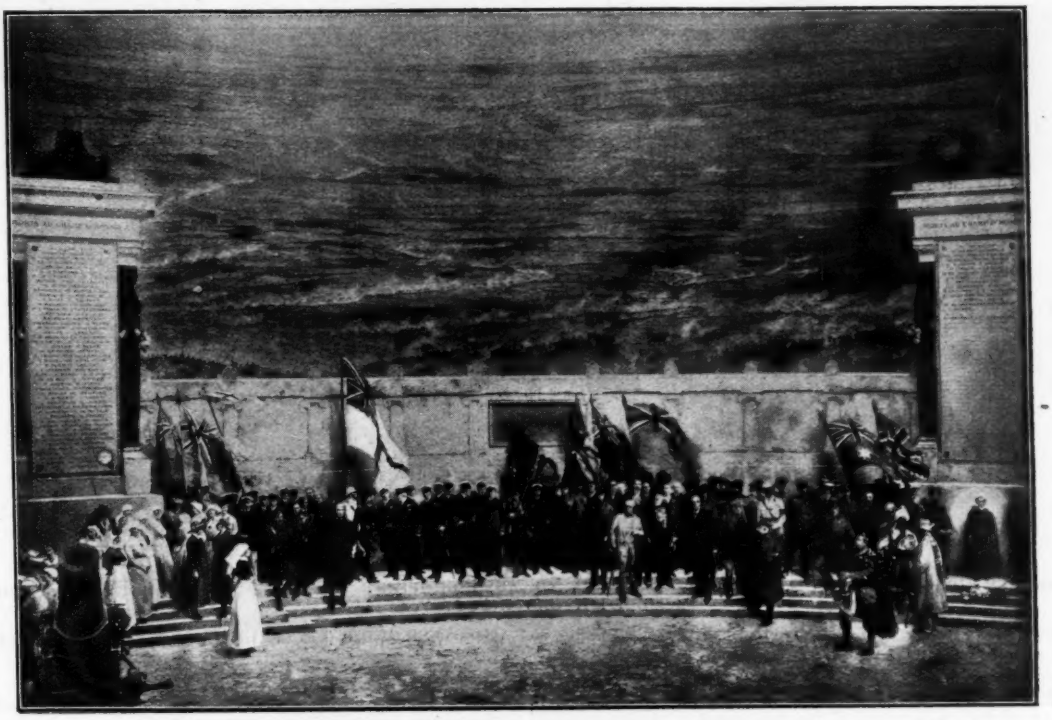
It is probable that at the end of last week those of the English visitors who are blessed with retentive memories knew more of Paris than of London; and it is regrettable that those of the party who were "born within sound of Bow Bells" were almost certainly the worst offenders. But the writer, who is guilty, has discovered comfort in his defection, for on his waxing eloquent on the wonders of one of "the sights" of Paris, his friend (a distributing gas engineer of that city) confessed to never having seen it! The friendship was thereupon cemented.

Arrangements had been made for the parties from the various hotels to meet at "The Grand" on Friday morning at 9.30, which allowed time for an introduction to Paris, in the full regalia of a beautiful summer day, before the rendezvous at the Arc de Triomphe. The route was carefully chosen to include streets and buildings of historic or æsthetic charm. After the ceremony described above, our diligent guides once more proceeded to dominate the picture; and in the result we arrived at the evening's festivities conscious that we had a good deal to learn from our French friends in the way of practical art and completed project, and incidentally as regards *esprit de corps* and its expression. These columns call only for the briefest description of what is not technical; an outline sketch of the salient features of a delightful programme must suffice.

The first halt after leaving the *Etoile* was at the Trocadéro—the State concert hall—a massive two towered building in a style which reminded one of Westminster Cathedral. This dominates a stretch of the river and the Champ de Mars, on which the Eiffel Tower rears its immense height over Paris, and incidentally set many of the party talking of broadcasting.



THE TEMPLE OF GLORY—PANTHEON DE LA GUERRE.



SEGMENT OF THE CANVAS DEVOTED TO THE BRITISH EMPIRE.

Thence we went to the Panthéon de la Guerre, in the Rue de l'Université, where France has sought to perpetuate, through the work of Carrier-Belleuse and Gorguet, the memory of the heroes of the late war. The periphery of the circular building suggests a vast canvas, in one piece, on which are faithful portraits of some 6000 of those whose valour or perseverance won the war for the Allies. The work, in quality and in the immensity of its detail, is marvellous; and the perspective achieved is almost uncanny, for in many instances it is difficult to persuade oneself that the painting is "flat." The lifelike effect certainly exceeds that gained by Wirtz, as exemplified in the Brussels gallery devoted to his work; and the photos which we reproduce must not be taken as doing justice to this. The work occupied upwards of five years and an infinite number of sittings by the celebrities who feature on the canvas; but the outcome is a wonderful record of a supreme effort.

M. H. LAURAIN,

Commissaire Général.

The tomb of Napoleon, in the Hôtel des Invalides, certainly merits the fame which attaches to it. Napoleon I. died and was buried in St. Helena; and it was not till some years afterwards that the French Government decided to transfer his remains to Paris. The Invalides was transformed for this purpose, and a magnificent resting place prepared for the national hero. The urn is covered by a massive tomb of red Finland granite, the gift of a Czar of Russia; and the whole lies on a sunken floor surrounded by a white marble balustrade, whence all can look down upon it and upon the battle trophies of Austerlitz and marble figures symbolical of his great victories. This part of the building is divided from the Chapel by the screen and a wonderful altar in dark marble and gold; and the tomb itself is approached by way of a tunnel closed by bronze doors behind the altar. The glass windows below the dome which towers over the tomb are of a light-blue shade, and those around the altar are coloured and arranged so that the latter always gives the effect of being flooded with sunlight. In the side chapels lie the remains of other famous soldiers—all except two, which await the last honours paid to Marshals Joffre and Foch.

Thereafter we returned to the hotels for lunch, and in the afternoon continued the tour. The heat of the day made doubly fascinating the halts in old buildings. The time spent at the Louvre was barely more than enough to whet the appetite for some more leisured visit; but our discriminating guide selected, among other priceless treasures, Venus of Milo, the Winged Victory, and the famous Monna Lisa, cut from its frame a few years ago and found again in an Italian antiques shop. And then the Panthéon, thrice a church, but finally dedicated as a memorial to St. Geneviève,

THE DELEGATES' BADGE.

the Patron Saint of Paris, and as a mausoleum for the famous dead. In the crypt lie buried the remains of Gambetta, Voltaire, Zola, Victor Hugo, and many great soldiers and sailors; while the body of the venerable building contains groups of memorial statuary, and the walls depict scenes from the lives of St. Geneviève and Joan of Arc. The paintings are mostly the work of de Chavannes; and one regretted not having the time to become better acquainted with a story so well told. The rest must be passed over—the Luxembourg, the Palais de Justice, even Notre Dame—except to lament, in regard to the latter, that modern art cannot produce the reds and blues that make old stained glass famous.

In England, we put Nelson on a plinth, crack jokes about it, allow extremists to make speeches at his feet, and omit to learn his history; and sixty out of a hundred men will pass the Cenotaph without uncovering. Not so in France; and "insularity" or "British phlegm" is really rather a poor excuse.

An Exchange of Greetings.

During the day it had not been forgotten that Mr. James Paterson was presiding over an important gathering at Wembley, and a telegram of greetings was dispatched to him from Paris. In the evening a wire was received from London (the text of which appears elsewhere in this issue). Mr. Tagg read this out at the

[*Photo. Mejat.*

THE PRESIDENT AND THE VICE-PRESIDENT ABOUT TO ADVANCE FIRST TO PLACE THE WREATH FROM THE BRITISH GAS INDUSTRY.

M. Rouland may be seen near Mr. Price and Mr. J. D. Smith, and Alderman Sir A. Ball is to the right of the photograph, behind Mr. Dunn and Mr. W. J. Smith.

banquet in the evening, and a round of applause signalized the Paris contingent's appreciation of the sentiment.

OFFICIAL BANQUET.

Hospitality on a magnificent scale was offered to the visiting delegations by the Société Technique on Friday evening. In the red and gold banquetting hall at the Hôtel Palais d'Orsay, over 450 covers were laid; and we were treated to good fellowship, good music, and a splendid example of the French culinary art. At the raised top table were M. Rouland (President of the Société Technique), M. Rolland d'Estape (the President-Elect), next to him Mr. Samuel Tagg, the Presidents of the Foreign Associations, and notable men referred to in M. Rouland's speech, and, to the joy of everyone, Mr. Henry E. Jones (President of the European Gas Company). At the lower cross table we noticed M. Laurain and Mr. W. E. Price.

M. Rouland's Speech.

At the close of the menu, M. Rouland rose to give "Le Chef de l'Etat, M. Gaston Doumergue, Président de la République Française." This having been honoured with enthusiasm and the singing of the "Marseillaise," M. Rouland proceeded to toast the Chiefs of State of the friendly nations from whom delegates had come to take part in their Congress. M. Rouland said: "Addressing the honoured representatives of the gas industry of these nations, I wish to express the profound gratification of French gas engineers at the really impressive response made to our invitation, and at the considerable part they have taken in the work of our Centenary Congress. Time prevents me from greeting individually each of our colleagues, and I must content myself with recognizing them all in the persons of the Chiefs of their delegation." Thereupon M. Rouland called in turn upon Mr. Tagg, M. de la Paulle (Belgium), Sgr. Gatell (Spanish), Heer Knottnerus (Dutch), Sgr. Sospicio (Italian), and MM. Nelkenbaum (Polish), Escher (Swiss), Keclik (Czecho-Slovakian). Each was received enthusiastically by the company.

The President of the Société Technique then passed on to eulogize the eminent Frenchmen present and to toast them in turn. They were: M. Georges Pointel, Vice-President of the Municipal Council of Paris, representing his President (M. Maurice Quentin); M. Juillard, Prefect of the Seine Department; Drouets, of the Ministry of Commerce, who had been good enough to distribute the Government Medals and bonuses awarded by the Société Technique to their employees; M. Labbé, of the Ministry of Public Instruction, who took a wide and active interest in the gas industry; and the engineering staff of Paris,

[*Photo. Mejat.*

THE BELGIAN (right of photograph) AND THE FRENCH DELEGATIONS TAKING UP THEIR POSITIONS.

M. Henri Laurain stands near the foot of the grave.

[*Photo. Mejat.*

THE WREATHS IN POSITION. THE PRESIDENTS AND VICE-PRESIDENTS AFTER THE SIMPLE CEREMONY.

whom he took as represented in the person of M. Bienvenüe. The valuable work of M. Célier, Chairman of the "E. C. F. M.," M. René Masse, and M. Siegler, Chairman of the Syndicat Professionnel, was recognized; and then M. Rouland turned to his successor, M. Rolland d'Estape. After referring to the success achieved by M. d'Estape in his early days, he mentioned that in 1903 their new President had become Manager of the Marseilles Gas Company, and had joined the Board later. He had entered the Société Technique in 1909, and was President of the Syndicat Professionnel from 1920 to 1924. In 1917 he was elected to the Board of the Gaz de Paris. Brilliant war service in the artillery had won him the Légion d'Honneur and the Croix de Guerre. In the coming year their ship would be steered by a hand of vigour controlled by a far-seeing, prudent, and brilliant brain.

M. Rouland then thanked all those who had worked so hard to make the Celebrations a success, mentioning especially the names of the Executive Chairman, M. Laurain, and the General Secretary, M. Pierre Mougin. The President concluded by appealing for the continuance of the excellent practices of meeting together in excursions or congresses, of studying the Technical Press of other countries, and even of exchanging engineers between the big works of France and other countries. "May these days of joint work, now nearly over, lead to a decisive step towards an old idea to which I hold more and more—the perma-

[*Photo. Mejat.*

A VIEW AT THE CLOSE OF THE CEREMONY.

nent international co-operation of our professional organizations!" M. Rouland then resumed his seat amid loud and prolonged applause, and shortly afterwards called upon the President of the Institution of Gas Engineers to reply first.

A TRIBUTE TO THE FRENCH GAS INDUSTRY.

Mr. TAGG said: "I am privileged and honoured by the duty imposed upon me, as President of the Institution of Gas Engineers, of conveying a message of friendship, goodwill, and congratulation on this historic occasion—the celebration of the centenary of the introduction of gas lighting into France and of the Jubilee of the Société Technique de l'Industrie du Gaz en France. I am confident that the sentiments which inspire the Council and members of the Institution, whose numbers now exceed one thousand, are fully shared by all other sections of the British gas industry, and that they desire to be associated with the expression of our sincere wishes for the continued success of the French gas industry and the prosperity of the Société Technique du Gaz. The truly marvellous progress which has distinguished your history during the past century has been triumphantly illustrated by the magnificent International Gas Exhibition, which has been fully described in the British Technical Press, and which we shall visit with feelings of pleasurable anticipation to-morrow. Other functions and ceremonies have served prominently to demonstrate your past achievements, and these have culminated in the influential gathering present to-night.

We have desired to intimate the vivid interest we take in your successful development by the presence of two of our Past-Presidents, Mr. A. E. Broadberry and Mr. Thomas Goulden, who have attended your meetings and participated in your deliberations in the early part of this week, and by the visit of a large number of our members who on the conclusion of our annual meeting in London, have hastened to share in your rejoicings. In this mark of respect we are supported by the thoughts and sympathies of our professional brethren at home, which are, with us, to-night warmed by ardent memories of your country and by the regard and esteem in which they hold the members of your Society who have visited British shores.

I would also wish you to believe that the French Gas Centenary Number of the "GAS JOURNAL," which so faithfully reflects and wisely inspires the views of the British industry, is a tribute to you on this occasion, intended to mark the intimate and friendly relation of the two nations which we desire to maintain and foster. In that Special Number will be found messages of cordial goodwill from the President of the National Gas Council of Great Britain and Ireland, Mr. D. Milne Watson; from Sir Robert Gardiner, who has long been associated with your Society; from the President of the European Gas Company, Mr. Henry E. Jones, who is present with us to-night; and from the Chairman of the Imperial Continental Gas Association, Sir Charles J. Jessel. We have this morning revived the memory of the common sacrifices made by the two nations in their recent victorious struggle for liberty. The unity of our peoples was marked by homage paid by our British colleagues at the Cenotaph at Whitehall at the same hour at which we rendered tribute to the illustrious dead at the grave of the Unknown Soldier, at the Arc de Triomphe.

The great industry with which we are associated is rendering a service of the highest order to the whole community, and it has prospered and will continue to prosper because it is so essential to its well-being and efficiency. With the restoration of order and liberty in France, the industry has made rapid strides; but to reach the objective we all desire and for which we are all striving—that is, to extend yet further the applications of gas—the attention of the general public must be drawn with insistence and devotion. Your efforts in this direction will meet with well-deserved success. We shall facilitate this progress by the intimate relation of engineers of both countries; and for this reason we welcome your visits to Britain, and eagerly seize the opportunity afforded to reciprocate those visits. The Institution of Gas Engineers of Great Britain send their fraternal greetings, acclaim your success, and express the sincere hope that the triumph of the gas industry in France in the century now opening will be even more brilliant than the one whose termination we are justly celebrating. *Vive l'Entente Cordiale!*"

A scene of renewed enthusiasm marked the close of the British President's tribute to the French gas industry and to the cordial relationship which exists between us; and "God Save the King" was sung by the whole company, led with fervour by the British delegates. Thereafter M. Henri Laurain read a French translation of Mr. Tagg's speech, which was greatly appreciated. The replies of the other chief delegates followed, the speech of each being received with applause and with the playing of the appropriate National Anthem. The speeches were all expressive of enthusiasm for gas, friendship for the industry in France, and hope for the future; and it is worth while recording the rhetorical masterpiece of Sgr. Sospicio in his own tongue.

The others who had been toasted were called upon in order; and the hour was late when the proceedings were brought to a close. Meanwhile the ladies of the party had been attending the performance of "Aïda" at the National Opera House; and they were enthusiastic in their appreciation of the talent and masterful setting which are always devoted to opera on the Continent.

Saturday, June 28.

OFFICIAL VISIT TO THE EXHIBITION.

This was a red-letter day for the Société Technique and the organizers of the Exhibition, for the new President of the Republic, M. Gaston Doumergue, paid an official visit to the Jardin d'Acclimatation. This was only his fifth appearance in public, and his popularity had yet to be gauged by the acclamation accorded him at the "Grand Prix" on Sunday; but this did not prevent his receiving a cordial welcome from the large crowd who made their way through the beautiful Bois de Boulogne, and thronged the entrance to the International Gas Exhibition. Two military bands lent colour to the scene, and contrasted with the immaculate tall-hats and morning coats of the group of French gas officials who awaited the Chief of State at the end of the carpeted approach. Near by were Mr. Tagg and the leaders of other delegations. M. Doumergue arrived soon after 10.30, the "Marseillaise" crashed out, a few presentations were made, and then he was conducted round the whole exhibition, evincing a keen interest in much that he saw. Finally he entered the Theatre, where all the *congressistes* had assembled, and passed slowly up the centre gangway, exchanging courtesies with certain members

[*Photo. Mejat.*

THE PRESIDENT OF FRANCE LEAVING THE EXHIBITION.

presented to him. Thence he departed by the main exit from the "Palmarium." In our photograph taken at this juncture, M. Doumergue is seen between M. Rouland and M. Laurain, while the new President of the Société Technique, M. Rolland d'Estape, follows (to M. Rouland's right in the picture).

All were then at liberty to wander through the Exhibition; and great interest was taken in the comprehensive display, contrasting as it did in many instances with our own practice. It is not our intention to enlarge to any extent on our previous account of the Exhibition [see "JOURNAL" for June 18, pp. 824-8]. General opinion seems to be that we are ahead of our friends over the channel in the matter of gas-consuming appliances—especially domestic ones; but it must be remembered that their temperament and the order and habit of their lives differ greatly from our own, and it is consequently hard to judge the nature of the demand for, or criticize the supply of, gas appliances. At the same time it is notable that a considerable business has been done at the Exhibition in the English type of high-class cookers, and this at a price that is bound to reflect the exigencies (for the French) of a rate of exchange hovering round 80 frs. to the £. The "N.G.C." standard cooker was given a prominent position, both upright and "eyelevel" types being shown. The best style of gas-fire on show closely resembles our own modern lines—at any rate exteriorly—but there were a number of small fires to be seen which we nowadays look upon with some suspicion. However, again we must bear in mind a Continental custom—that of house warming by the anthracite or coke "calorifère," or by central heating, which is even more firmly entrenched in tradition than the open fire is with us.

About one thing there is no doubt; the Committee of the Centenary—the gas industry of France, in fact—are to be congratulated on their efforts. As early as October, a small band of enthusiasts started work at the Jardin d'Acclimatation. It was not only a question of stand construction and pipe running, for the accommodation as a whole was in an extremely dilapidated condition, and much builders' work had to be carried out. They are now satisfied that their labours have not been in vain; and the public must certainly know a great deal more about gas than formerly, for on the second Sunday of the exhibition's run over 25,000 people are reported to have visited the Gardens.

On presentation of a ticket, supplied in a handy book together with passes to all the functions, members of the visiting parties were able to obtain from the office of the exhibition a very handsome souvenir book. This is a beautifully printed and illustrated volume, and an opportunity will be taken to publish a brief review of its contents.

The writer desires to express his thanks for much kind attention and help offered him by the staff at the exhibition, and by others whose time was fully occupied with the organization of the visit—especially M. Mougin, the General Secretary, and MM. George Reclus and Edouard Pourcelle.

THE WORKS OF THE STE. DU GAZ DE PARIS.

On Saturday afternoon the whole party of *congressistes* were the guests of the Société du Gaz de Paris. At 2 p.m. they were received at the palatial headquarters of the Company, and immediately embarked in a fleet of omnibuses marshalled in the Rue Condorcet.

LANDY.

An illustrated description of this station, translated from the brochure distributed at the works, appeared in our French Centenary Number for June 18 last, and readers are referred to this for details of the plant. The Company had wisely decided, owing to the very full programme before the visitors, to make a special point of their carburetted water-gas plant, and not to encourage anything approaching a complete survey of the works. Thus the hope we had expressed that the neighbouring site—Le Cornillon—might reveal new plant of great interest, did not materialize, though a building of considerable proportions was observed in course of erection there.

On arrival at the works, we were led straight past the long line of retort-houses, and the formidable array of coke screens, to the new buildings which house the water-gas installation and its auxiliary plant. As we have pointed out before, it is only comparatively recently that water-gas manufacture has been permitted in France; and they are still limited to a 15 p.ct. carbon monoxide content. In exercising their new powers in this direction, the Société du Gaz de Paris have profited to the utmost from recent developments, and the result is a very fine plant. At present four 2 million c.ft. sets are in working, and the erection of two more, to complete the projected lay-out, has been commenced. Arrived on the operating floor, the visitors received a short lecture on the plant from M. Laurain, who was aided by a pair of large-scale drawings. The plant is of Humphreys and Glasgow's design, with the latest pattern of Babcock waste-heat boilers (which can be by-passed with the aid of valves and an interesting type of cut-off) and roller grates. The coke is fed from overhead hoppers into the generators—direct except for the elimination of breeze by a cascade screen near the mouth of the chute. This directs the breeze into skips which are taken down the lift and to the boiler house, where the fuel is disposed of in the most efficient manner. The scrubbers and final water-vapour condensers make a formidable battery outside the main building, while the blowers and the meter are situated in separate "houses" under the one roof.

Many of the party, returning to the omnibus park, remarked the several small holders with the old-style inlet and outlet pipes entering the crown of the structure, and incorporating a pair of swivel joints to allow for the rise and fall of the single bell. Two inlets and two outlets are necessary for the even distribution of the weight. Comment was also forthcoming as to the prodigality displayed in the design and lay-out of the coke screens. The installation savours of the magnificent; but one cannot help thinking that in England the coke would have been screened and that a few extra retort-houses would have appeared on the scene as well.

LA VILLETTE.

The Grand Fleet then weighed anchor and proceeded to the La Villette Works of the Company, which were included in the programme contrary to expectations but to the general satisfaction. Here, again, time allowed only one feature of the works to be inspected; but as this was of great interest to all the decision was a popular one. Chamber ovens are rare in carbonizing practice in this country; and in consequence observation was keen and comment, favourable and otherwise, general among the English contingent. Everything seemed very "nice and easy"; the charging machine pursued the even tenor of its way above the battery; the red-hot cake of coke (seemingly without time to smoke) rushed with incredible speed into the quencher as soon as the great door swung quietly open; and shortly afterwards it was seen, good in size and colour, being conveyed to the screening plant opposite the battery. It is intended to publish as early as possible a translation of the brochure which was distributed among the visitors; and we hope to be able to obtain from the Company some detailed results of the working of this plant.

An inspection of the Diesel engine and high-tension electricity generating station and of charts and drawings set up in an office near the entrance, brought a most interesting phase of the trip to a close. The "Gaz de Paris" merit the thanks of all.

AT THE HÔTEL DE VILLE.

The Municipal Council of Paris next assumed the rôle of host to the large number of delegates and their ladies; and the scene changed from the sombre works on the outskirts of Paris proper to the magnificence of the Guildhall in the midst of its beauties. Once more we feel that our pen is incapable of doing justice to, indeed of describing in any way, the lavish art and decoration which greet one within. An impression is left of a stately staircase and a long wide gallery with comfortable chairs and settees and a profusion of marble. The pillared reception hall is open to this gallery, and from the former one passes through an anteroom into the ball-room. The painted ceilings and the pictures in oils on the panels of the walls themselves compel admiration—in fact, one could but wish for an opportunity to wander through on some more leisured occasion.

On a dais in the hall were the band of the Garde Républicain, which Frenchmen hold to be the finest military band in the world; it is a fact that each member of it has to pass his studies at the Conservatoire. The brilliance of the setting was preserved by the bright gold of the chairs ranged round for the guests. Presently there arrived in procession the President of the Council, the Prefect of the Seine Department, other dignitaries of the city, and M. Rouland; and the official welcome was made—commendable in its brevity, but none the less cordial. M. Rouland, in replying, on behalf of the gas industry, to the President and the Prefect, presented the leaders of the various delegations. Thereafter a delightful programme of music was rendered by the band; and light refreshments were served in the ball-room.

Sunday, June 29.

An early start was imperative in the morning; a special train leaving the Nord Station at 7.50, which conveyed the party with all speed to Douai. It was a most interesting journey, lying partly through the Somme Valley and battlefield; and many were the ejaculations of surprise and reminiscences of less pleasant days. But everywhere there are signs of renewed life and industry; the blasted trees being in many places the only signs of the desolation that once reigned supreme.

ETABLISSEMENTS ARBEL—THE TANKLESS GASHOLDER.

The Arbel Factory make railway wagons and undertake general steel construction, and are affiliated to a coke-oven works 4 kilos. away. Founded in 1895, the establishment originally employed 40 men, who were brought from another part of the country, as artizans could not be found locally to deal with the firm's work. During the war, the Boche took possession; and on his evacuation it was discovered that the plant had been removed, lock, stock, and barrel, to Germany. M. Arbel thereupon decided to reinstate his property, but with the determination to use no coal on the works. Consequently we find a demand for 150,000 cub.m. of gas a day, which is piped from the above-mentioned coke-ovens and stored in the chief feature of the day's excursion.

The tankless gasholder at the Arbel Works was built by Messrs. Bonnet Spazin. Its present capacity is 27,000 cub.m., but it is intended to extend it to 40,000 cub.m., or nearly 1½ million c.ft. Arrived at the holder, the party listened to an explanation by M. Arbel of his works and particularly the holder; and then an ascent was made in groups of ten, the galleries not being designed to carry a large live weight.

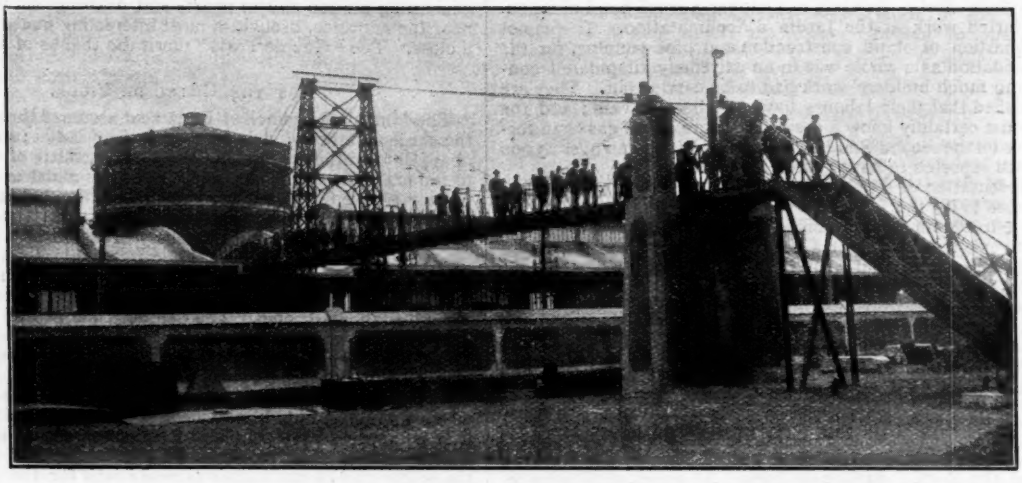
We shall await an opportunity for publishing a full description of the piston type of gasholder, meanwhile referring our readers

to the "JOURNAL'S" earliest reference to the invention [Vol. 130, p. 135], and to our translation of M. Bonnet's paper to the Société Technique in 1922 [Vol. 159, p. 268]. Abstracts of patent specifications have recently appeared in our "Register of Patents," the last one [June 25, p. 909] dealing with a form of collapsible ladder to the disc. These, together with the excellent model on view at the Institution meeting last week, and illustrated in this number [p. 189], render a few general remarks sufficient for the moment. The greatest saving in construction is of course realizable, especially in medium-sized holders, from the absence of the expensive tank; but this is not the only direction in which to look for economy. Erection becomes considerably facilitated, for the method employed is to complete the closing disc and support the roof over it when only a few rows of plates are in position; and then the disc becomes the working platform, being raised by air pumps as required. The fact that the disc is normally found to be tight during this operation—that is to say, before any sealing fluid is running—speaks volumes for the design

THE EXCURSION TO DOUAI AND ST. QUENTIN.

"STOP-PRESS" PHOTOGRAPHS.

THE photographs reproduced on this and the facing page will be of personal interest to many of our readers; while for ourselves they have an additional interest in that for the first time in the history of the "JOURNAL" the aeroplane has helped us to press. The views were taken last Sunday; and M. Paul Méjat, of No. 59, Rue de Rivoli, who acted as photographer for us, only arrived back in Paris by the special train just before 8 30 p.m. In 48 hours, therefore, the photographs were developed and printed, expressed to England by air, and half-tone blocks prepared. The report of the day's excursion falls on pp. 191-2.



VIEW OF THE ARBEL HOLDER FROM ACROSS THE RAILWAY.

[*Photo. Méjat.*

M. ARBEL EXPLAINS.

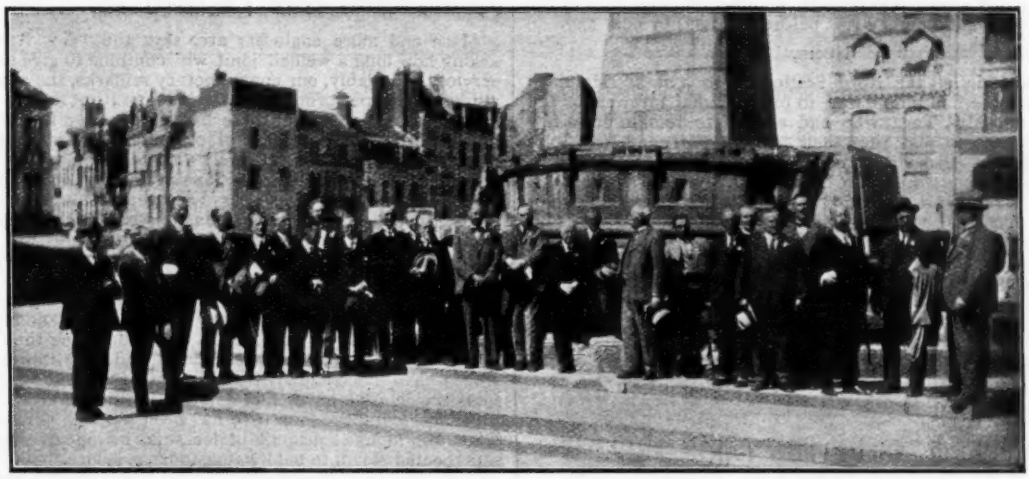
of the all-important "joint." Last Sunday at Douai one of the pump chambers was open, and the writer was struck by the compactness of this apparatus, especially of the electric motor and small rotary pump.

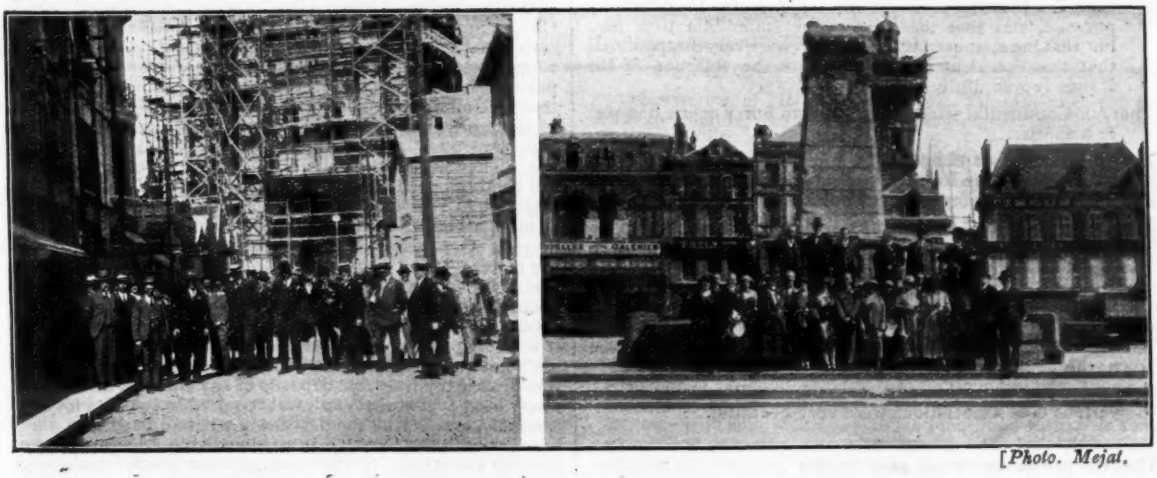
Favourable impression was voiced on all sides, after the majority of the visitors had climbed past the two intermediate galleries to the top one; many completing the job by descending the collapsible ladder on to the disc itself. It is understood that for holders of medium size the tankless variety runs about level in cost with the spiral-guided holder; and certainly the completed structure is quite a presentable landmark. The popularity of the type is rapidly growing—M. Bonnet has recently taken orders for three more in France, one of a capacity of over 7 million c.ft. We look forward to the erection of the first tankless gasholder in England.

DOUAI AND ST. QUENTIN.

The Municipal Council of Douai provided a welcome and

THE MARKET SQUARE AND BASILIQUE OF ST. QUENTIN.





[Photo. Mejat.

luncheon for the large gathering, after which speeches were made by the Mayor and M. Rouland, and by M. Jourdain and M. Frère, respectively the Chairman and the Engineer of the St. Quentin Gas Company. Then we re-embarked in the special train, and were transported to St. Quentin.

At this juncture it was decided that for the English contingent a stroll round the old town would be more acceptable than a visit to the gas-works, which were completely destroyed during the war. They have been rebuilt, however, and it is notable that already they have regained more than half of their lost consumers. In the main square of St. Quentin, therefore, the professional and several amateur photographers had their opportunity; and then the Basilique was visited. This fine old church was used by the Germans as an observation post, with the inevitable result; and the authorities consider that it will take fifty years to complete its reconstruction, so short are skilled labour and materials. Round the main walls of the edifice, about 5 ft. from the ground is a series of 92 holes made by the Boche to receive demolition charges prior to his withdrawal in 1918. Only the arrival of the French before they were expected prevented the Basilique from being past all repair.

Tea served in the Palais de Justice, at the invitation of the township, was the last item in the long and most enjoyable programme.

M. ROULAND'S FAREWELL.

There was a short speech of welcome, and then M. Rouland mounted the platform amid applause. They had, he said, arrived at the last halt on a memorable visit. Calling attention to a swallow flying high in the great hall where they were assembled, he said he took the omen as a presage of good for the gas industry. He introduced to the company M. Frère, the Engineer of the local gas undertaking. In the closing days of his life—he was 81 years of age—he had made a tremendous effort in reconstituting his works; it was a veritable *tour de force*, and M. Frère merited their congratulations. To wish him god-speed was a very fitting close to their congress. After words of thanks to the Chairman of the Company (M. Jourdain) and a toast to the Municipality, M. Rouland declared the congress closed, wishing god-speed to all until the next centenary.

M. Frère was accorded musical honours by the English visitors; and the "Marseillaise" concluded the proceedings after a brief reply by M. Jourdain. And so back to Paris, with a number of the *congressistes* wrapped in peaceful slumber and dreaming of the possibility of a good night's rest before the journey next day.

HOME.

The boat train left the Nord Station at 10 a.m. on Monday; and all were there in ample time to bid a cordial farewell to the President and Mrs. Tagg, who had elected to remain for a few days in France to rest after their labours. Mr. and Mrs. John Wilkinson were also left behind for a holiday, and Col. W. R. Glover was among those who witnessed, from the platform, a departure the musical accompaniment of which reminded one of the war. The journey passed pleasantly—luncheon on the train was welcome, as were the fresh breezes of the Channel; and England seen from the *Invicta* and the train to London was no less acceptable by reason of a few days' absence.

Thus ended, in the history of the Institution, a year full of useful work and progress, and a trip fraught with good-fellowship and hospitality enjoyed; and as a background to the picture which all will carry in their memory is the charming personality of the President and his lady.

IMPRESSIONS OF THE PARIS TRIP.

By a CHIEL YE KEN.

The geniality and good fellowship of the party.

That the President's speech at the banquet was most happily phrased, and that the microphone suited him to a tee; but that the members at the banquet were very disappointed that the President did not emulate the embrace of the Italian representative.

That our Continental friends don't like to hurry over a banquet or a speech.

That the assembly and banquet commenced before 8 p.m. and carried on till the following morning, and that some glasses were filled and emptied in the process.

That the Belgian Gas President is evidently an orator.

That the British Legion never sang the National Anthem more heartily than it was sung at the banquet, and that they will probably be asked to repeat the performance at Wembley.

That there is a wonderful spiritual appeal in the undying flame at the Unknown Warrior's tomb.

That the wreaths laid on the tomb by the Presidents of the various Gas Associations were very beautiful.

That the gas-works visited gave further point to the fact that an official visit is a fine opportunity for a general clean up.

That sight-seeing with the temperature keeping time to the rate of exchange can be fairly tiring.

That the Parisian does not seem to sleep at all.

That the French really enjoy life, and the open air.

That a roll and a cup of coffee make a delightful breakfast—in Paris.

That the afternoon cup of tea was the biggest miss on the trip.

That a good accent and a smile are better for getting about intelligently than a splutter of bad French.

That the Paris buildings and arches and bridges and parks take some beating.

That they are Napoleon's finest memorial.

That some members of the party were surprised to learn that they were mostly designed by Scotsmen.

That it is a Scot—disguised as Napoleon—who occupies the top of the most important obelisk in Paris.

That a brief visit to the Louvre and other galleries reveals a deplorable absence of method in the lingerie business of the past.

That Paris taxis have brakes, and that these are fine advertisements for their makers.

That reckless expenditure was the order of the day—with the franc at the equivalent of a threepenny bit.

That a member of the party was reported to have tipped a taxi driver a whole franc!

That members found a new and excellent device for determining who should pay.

That a strong Band of Hope party lines the banks of the Seine, but that there seemed to be more fishers than fish.

That Sunday in Paris is a little different from Lambeth.

That the farewell at the Nord lacked nothing in enthusiasm.

That the English Channel was glorious and on its best behaviour.

That the chalk cliffs of Old England and the trim clean fields and the attractions of home had not grown stale, but were as alluring as ever.

Life of Welded Joints.

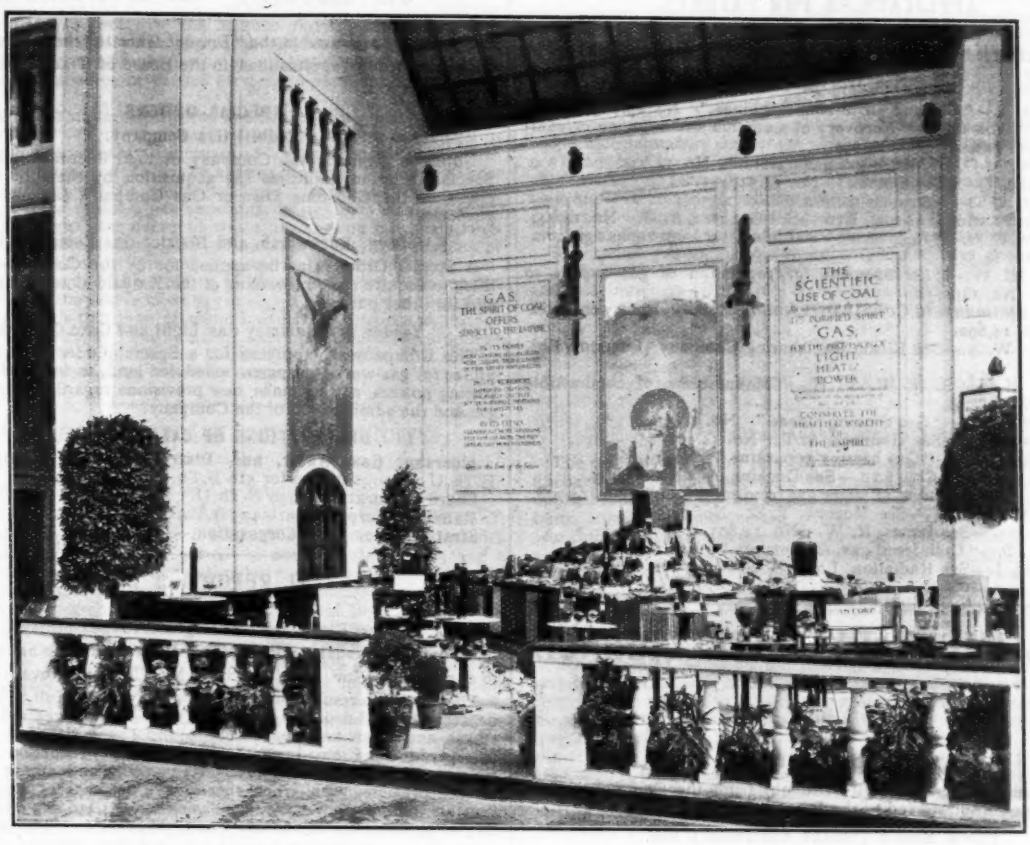
More and more engineers are, says the "Gas Age-Record," asking how long a welded joint will continue to give satisfactory service. Probably, our contemporary remarks, the answer lies in records of the performance of welded lines; but the oxy-acetylene industry is so young that there has hardly been time to build up long records. The welding of pipe lines for the high-pressure distribution of gas is a relatively new development. One or two outstanding examples, however, can be found in plant-piping fabricated by welding. The year 1915 represents almost ancient history in the oxy-acetylene industry; but in that year a large plant installed 1100 ft. of 12 in. diameter high-pressure steam line with welded joints. This line was built of extra heavy pipe, butt-welded, and every joint made with the oxy-acetylene blowpipe. When the line was completed, it was tested at a 300-lb. hydrostatic pressure, and not a single leak developed under this test. The line has been in continuous operation since the day it was installed, and never has a leak developed. So thoroughly convinced have this company been that oxy-acetylene welding represents the solution of all pipe-joint difficulties, that all the piping they have installed since 1915 has been welded. These installations total many thousands of feet, and include everything from superheated steam to cold water under pressure.

Gas-Meter Accuracy.

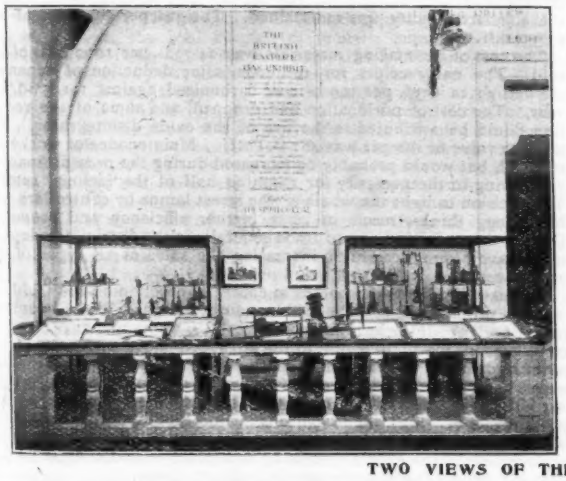
Writing in the "United Gas Improvement Circle," Mr. W. A. Castor, Superintendent of Meters at the Philadelphia Gas-Works, states that upon the leasing of these works by the Company in 1897, the meters then in service were removed as rapidly as possible, for the purpose of testing and repairing them, and giving them a United Gas Improvement Company number. The meters in their original condition, owing to their colour, were termed "black meters," and when tested and repaired they were painted red. They were thus easily distinguishable from those which had not been removed by the Company. In some cases these black meters had remained so long in service that the customers had become attached to them, and were reluctant to have them replaced. One case of this kind stood out above the others, and the meter was not removed until last January. This meter, the last of its vintage, was made by the American Meter Company about fifty years ago, and was of the open-top type fitted with a rotary valve. It had been connected at the address from which it was removed for at least twenty-seven years, and very likely for a much longer period. It was correct (100 p.ct.) when tested, and was practically free from deposits of any kind. At no time had this meter been overworked, as it was required to pass gas for illumination only, and during the past few years had been shut off. This, together with the fact that it was located in a warm cellar only a few feet away from the furnace, explains partly, the writer says, the wonderful condition, both inside and outside.

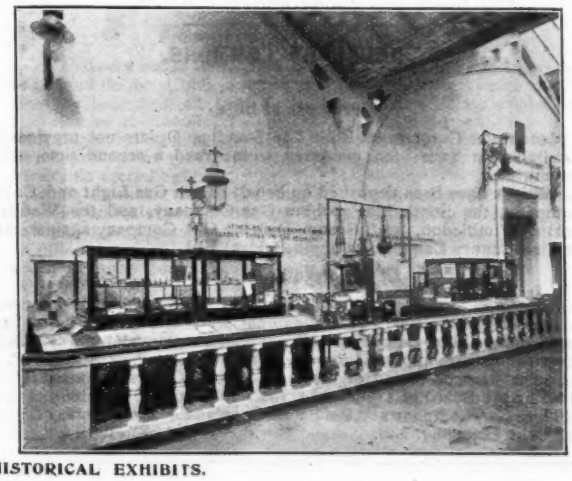
BRITISH EMPIRE GAS EXHIBIT.

Further Views.



THE PART OF THE GAS EXHIBIT DISPLAYING BYE-PRODUCTS, AND DEMONSTRATING THE SCIENTIFIC USE OF COAL.





TWO VIEWS OF THE HISTORICAL EXHIBITS.

Heating and Ventilating Engineers.

The members of the Institution of Heating and Ventilating Engineers, whose annual meeting was held last week, terminated their proceedings with a visit to Wembley, when a party of between sixty and seventy members paid a visit to the Gas Exhibit. The special items of interest to technical men were explained and demonstrated by several guides who conducted the party round the Exhibit, after which the members took tea together in the Regent Restaurant.

Surveyors at the Portslade Gas Works.—In connection with a conference of the Surveyors' Institution in Brighton on Thursday of last week, several alternative visits to local works of interest were arranged. One party went to the Portslade Works of the Brighton and Hove General Gas Company, where they appeared thoroughly to enjoy themselves, and showed great appreciation of an illustrated booklet giving particulars of the plant, which Mr. C. H. Rutter (the Engineer and General Manager) had had prepared for the occasion.

Institution of Civil Engineers.—On Tuesday next the James Forrest Lecture, entitled "Electrical Progress and its Unsolved Problems," will be delivered by Prof. Elihu Thomson, who will be presented with the Kelvin Medal on Thursday, July 10. The Conversazione will be held next Wednesday, from 8 to 11.30 p.m., at the Institution of Civil Engineers, Great George Street, Westminster, S.W.1.

Combustibility of Coke.—The "Gas Age-Record" quotes from an article by Herr F. Heyd, in which the statement is made that the combustibility of coke depends upon two factors: (1) The area development of the coke and the structure of the surface, conditions which decrease the surface development decreasing likewise the ease of combustibility; (2) the chemical constitution of the surface. The chief constituents of cokes are the organic substances, the inorganic ash, and the reaction products of the organic and inorganic constituents. The difficulties in burning cokes increase with amounts of ash above 1 p.ct., and with large amounts of reaction products. An easy burning coke by high heating in a neutral atmosphere does not lose any of its power of reduction. The great hardness of cokes which are difficult to burn is due to hard reaction products.

REGISTER OF PATENTS.

APPLICATIONS FOR PATENTS.

[Extracted from the "Official Journal" for June 25.]

Nos. 14,479 to 15,045.

DOCKING, A.—"Gas and air mixing machines." No. 15,005.
FORST, P. VON DER.—"Recovery of ammonia and ammonium compounds from gases." No. 14,777.
GLASGOW, A. G.—"Water-gas generators." No. 14,744.
HANSFORD, J.—"Gas-meters." No. 14,547.
HOUNAM, A. T.—"Dry gas-meters." No. 14,592.
HUMPHREYS AND GLASGOW, LTD.—See Glasgow, A. G. No. 14,744.
IRONSIDE, E. A.—"Recovering volatile solvent from vapour gas mixtures." No. 14,555.
JAMES, R. W.—"Arrangement for regulation of gas supply to burners." No. 14,893.
KITSON ENGINEERING COMPANY (LONDON), LTD.—"Rotary compressors." No. 14,892.
M'NUTT, W. A.—See Kitson Engineering Company (London), Ltd. No. 14,892.
MOORE, H. L. S. & W. S. H.—"Manufacture of combustible gases." No. 14,798.
MORROW, T. E.—"Gas cooking stoves." No. 14,574.
PEEBLES, W. C.—See Hounam, A. T. No. 14,592.
RADIATION, LTD.—"Gas heating apparatus." No. 14,965.
RITCHIE, HART, & CO., LTD.—See Docking, A. No. 15,005.
RUDE, J.—"Production of water gas from solid fuel." No. 14,708.
SHALE, W. & W. E.—See Morrow, T. E. No. 14,574.
SIEDEX GES.—See James, R. W. No. 14,893.
SIMPSON, S.—"Coin-freed gas, &c., meters." No. 14,630.
YATES, H. J.—See Radiation, Ltd. No. 14,965.

PARLIAMENTARY INTELLIGENCE.

HOUSE OF LORDS.

Progress of Bills.

Rotherham Corporation Bill: Brought from the Commons; read the first time; and referred to the Examiners.

Public Health (Smoke Abatement) Bill.

A Bill to amend the law relating to smoke nuisance and for other purposes was presented by Lord Muir Mackenzie, on behalf of Earl De La Warr, on the 26th ult., and read the first time.

HOUSE OF COMMONS.

Progress of Bills.

Manchester Corporation Bill: The Standing Orders not previously inquired into have been complied with; read a second time, and committed.

Petitions have been deposited on behalf of the Gas Light and Coke Company, the South Metropolitan Gas Company, and the Wandsworth, Wimbledon, and Epsom District Gas Company against the London County Council (Lambeth Bridge) Bill.

Gas Regulation Act.

In the House on the 17th ult. the drafts of Special Orders proposed to be made by the Board of Trade under section 10 of the Act on the applications of the Burton-upon-Trent Corporation and the Walsall Corporation were approved, on the motion of Mr. Albert Alexander.

Copies were presented of drafts of Special Orders proposed to be made by the Board of Trade under the Act, on the applications of the Reading Gas Company and the South Bank and Normanby Gas Light and Coke Company, Ltd.

The Patent Office Report.

The applications for patents in 1923 numbered 32,621, as compared with 35,494 in 1922, 35,132 in 1921, and 36,672 in 1920. The number sealed, however, last year was 17,073, which compares with 14,191 in 1920. There were filed 18,708 complete specifications—352 less than in 1922. The receipts from patents fees during 1923 amounted to £393,615. Last year the applications made by way of communication from abroad numbered 1348, as compared with 1476 in the preceding twelve months. Opposition to the granting of patents was entered in 168 cases. The number of applications made for the restoration of patents which had lapsed in consequence of the non-payment of renewal fees was 64, and in the 47 decided cases the patents were restored. Under the section of the Act which empowers the Comptroller to revoke a patent upon application made within two years from the date of the patent by any person who would have been entitled to oppose its grant, four cases were decided. In three of these an order requiring amendment of the specification was made, and in the fourth the patent was, with the consent of the patentee, revoked. For extensions of the term of patents, 23 applications were made, covering 32 patents. In the twelve decided cases, extensions ranging from one to four-and-a-half years were granted in eleven cases covering fourteen patents, and one application was refused. There are now 58 patents in force which have been prolonged beyond the normal period.

MISCELLANEOUS NEWS.

GAS REGULATION ACT APPLICATIONS.

There have appeared in the "London Gazette" the following further notices regarding applications to the Board of Trade under the Gas Regulation Act.

SPECIAL ORDERS.

Redhill Gas Company.

Notice is given by the Company of their intention to apply for a Special Order to authorize the acquisition by them of the undertaking of the Godstone District Gas Company, Ltd., and for other purposes.

Welwyn, Knebworth, and District Gas Company, Ltd.

A Special Order is to be applied for by the Company, to enable them to acquire the undertaking of the Hatfield Gas Company, Ltd., and for other purposes.

Yeadon and Guiseley Gas Light and Coke Company.

The Company are applying for a Special Order to purchase and utilize for gas-works purposes scheduled land, to increase their borrowing powers, and to make new provisions regarding the supply of gas and the admistration of the Company.

DECLARATIONS OF CALORIFIC VALUE.

Aldershot Gas, Water, and District Lighting Company.—500 B.Th.U., in substitution for 510 B.Th.U. (Sept. 29.)
Chard Corporation.—450 B.Th.U. (July 1.)
Mansfield Corporation.—475 B.Th.U. (June 15.)
Stratford-upon-Avon Corporation.—410 B.Th.U. (Sept. 20.)

ANNUAL REPORT AT BURNLEY.

Mr. J. Herbert Clegg, the Gas Engineer to the Burnley Corporation, has issued his annual report. Mr. J. P. Leather, who has retired, was in charge until Nov. 18, after which Mr. Clegg took over the duties.

The financial result is a net profit of £13,828. Full allowance for depreciation and depleted stocks was made, £6000 credited to meters, stoves, and lamps extension accounts, and £2000 placed to income-tax reserve fund. From June there has been a reduction of 1d. per therm. The make of gas was 865,851,000 c.ft., an increase of 4·9 p.ct. on the previous year, when there was a decrease of 0·5 p.ct. The greatest amount sent out in one week was 23,456,000 c.ft., and the largest consumption in one day was 3,788,000 c.ft. The gas sold by meter in 1914-15 was 675,676,082 c.ft., and last year 727,067,959 c.ft. For that period the gas unaccounted-for varied from 3·77 p.ct. to 3·62 p.ct. on the make. Mr. Clegg says they had been successful in obtaining a further 206 c.ft. of gas per ton of coal carbonized; while the standard quality was maintained. The gas per ton of coal was 13,331 c.ft.

The cost of gas-making materials was 24·79d. per 1000 c.ft. of gas sold. The net receipts for residuals, after deduction of expenses, showed £1 2s. 0·3d. per ton of coal carbonized, against 18s. 5·8d. last year. The cost of purification had dropped, and some of the reduction could be attributed to the use of the oxide disintegrator. The average value of the gas was 482 B.Th.U. Maintenance of works was reduced, but would probably be increased during the present financial year owing to the necessity for resetting half of the inclined retorts. The decision to light the whole of the street lamps by controllers will, Mr. Clegg thinks, result in some further efficiency and economy. Despite the poor condition of trade generally in the district, the department have been successful in increasing the sales of all types of gas appliances.

The new 3 million c.ft. holder in course of erection on the Old Hall site will probably be completed this month, but gas will not be turned into it until about the beginning of August. The maintenance of works costs are still too high, owing to the advanced age of the bulk of the plant at disposal. The item under the heading of coal-gas making wages has been gradually brought down to 4d. per 1000 c.ft., which Mr. Clegg regards as a minimum with the existing plant, and at the present rate of wages. The figure is far too high in comparison with works of more modern construction. The remedy—that is, a complete replacement of the existing works by new plant—decided upon by the Council, should therefore be applied without delay.

Newbury Gas Affairs.—At a recent meeting of the Gas Committee of the Newbury Town Council, it was reported that the sanction of the Ministry of Health to a loan of £1250 for the provision of a waste-heat boiler at the gas-works had been received, and a grant of 50 p.ct. of the interest on the loan for a period of 15 years promised by the Unemployment Grants Committee. The order for the boiler had accordingly been placed with the Woodall-Duckham Company, Ltd. It was reported that an Order had been made by the Board of Trade, with the approval of Parliament, under section 10 of the Gas Regulation Act, 1920. By the Order, the Corporation's limits of gas supply are extended so as to include the parishes of Enborne, Newtown, Sandleford, Speen, and Shaw-cum-Donnington; the portions of the parishes of Cold Ash and Thatcham which were specified in the draft Order submitted on behalf of the Corporation; and the portions of the parish of Greenham in the vicinity of the existing gas mains of the Corporation. The Corporation are also authorized by the Order to supply gas by agreement to any property in the parish of Greenham belonging to or in the occupation of the Newbury Racecourse Company, Ltd., Mr. Lloyd Harry Baxendale, or a Railway Company. The Committee recommended that, as from the meter readings for the quarter ended March 31 last, the prices of gas be reduced as follows: Ordinary consumers 11d. per therm, and prepayment consumers 1s. per therm.

OLDHAM GAS ACCOUNTS.

Presenting to the Oldham Corporation Gas Committee the accounts for the year ended March 25 last, Mr. Ernest Parry (the Commercial Superintendent) says the gross revenue amounted to £342,905, and the gross expenditure to £268,253; the balance carried to profit and loss account being £74,652. The net profit on the year's working was £31,754. The debit brought from the previous year was £49,020, and the debit balance to be carried forward to next year's accounts is £24,766.

During the year under review, the average price per ton realized for coke and breeze was 28s. 0·69d. The receipts for tar amounted to £29,997, which represents an increase of £5533 over last year. Ammoniacal liquor realized £3027, as against £3670. The average cost of coal carbonized was 26s. 0·82d. per ton—a decrease of 1s. 6·65d.; and the net price realized per 1000 c.ft. of gas sold was 3s. 5·88d. The quantity of gas manufactured was 1,617,447,000 c.ft., compared with 1,621,477,000 c.ft. in the preceding year. The total number of meters fixed at March 25 last was 57,240—an increase of 193 as compared with last year. The number of prepayment meters in use has increased during the year from 12,745 to 16,252; and the quantity of gas consumed through this type of meter has increased from 186,264,700 c.ft. to 237,104,900 c.ft. The actual number of consumers on March 25 was 53,015, or 212 more than on March 25, 1923. The total storage capacity of the three works is now 10,680,000 c.ft.

COMPETITION OF GAS AND ELECTRICITY.

In the course of a paper read at the Annual Convention of the Incorporated Municipal Electrical Association held at Chester recently, Councillor HAMMER (Mayor of Hackney), who dealt generally with the purpose, policy, and management of public undertakings, had a short section dealing with competition between gas and electricity. He said that where both gas and electricity undertakings were owned by the municipality it still frequently happened that there was a sort of restricted competition between them, though it was the electric end which usually appeared to get the restriction. This was rather a short-sighted policy, as experience had shown that, when both these services were in the hands of a municipality, it was better to let them develop independently as separate organizations. With showrooms and publicity, each should do its best to get business on sound lines. There could be little doubt that active competition between suppliers of electricity and gas had been of very great value to the public in the last few years. It had raised the standard of lighting, stimulated inventors, helped the manufacturers, and given all much greater facilities, and more economical methods of using heat energy, than they could possibly have had under some sort of protection for either side. The argument was often put forward that a private company was a ratepayer, and should not be subject to such competition from the municipally owned electricity undertaking, but the author maintained that it was all to the good that there should be complete freedom of action in this respect. The municipal undertaking paid rates; and careful examination of the book-keeping of modern municipal enterprises would show nothing to suggest that competition between them and a private undertaking was in any way unfair.

Mr. B. SANKEY, Manager of the Johannesburg Corporation electricity and gas undertakings, said, in the subsequent discussion, that, though he did not know of a single gas-lamp in any private house or business premises in Johannesburg, the two undertakings were progressing satisfactorily. The electrical concern was connecting from 150 to 200 new consumers per month; while the gas-works were in the position of not being able to take on any more consumers, and new gas-works, at an estimated cost of £250,000, were to be erected. He did not altogether agree with the author in his remarks upon the competition between electricity and gas. Unrestricted competition, as advocated, had its good points, but it also had its bad points. It meant duplication of expenditure, because both gas and electricity mains had to be laid in the same street sufficient to supply all the wants of every consumer. If the undertakings were in the hands of the municipality, but under separate committees and engineers, then the gas engineer wanted to do everything by gas, and the electrical engineer wanted to do everything by electricity. The result was that a good deal more money was spent in capital outlay in any particular street than the real economics of the case warranted. In the end, the consumer had to pay; and personally he believed that if the two undertakings were under one responsible manager, then they would obtain that restricted monopoly which was the best in the long run. If there were separate undertakings in charge of different managements and committees, there was not that co-operation and co-ordination which there should be. In Johannesburg, where the two undertakings were in the same hands, he had found the greatest difficulty in keeping pace with the development of both of them.

Croydon Gas Students in the City of London.—A party of students in gas manufacture and supply from the Croydon Polytechnic, drawn chiefly from the Croydon Gas Company, accompanied by Mr. Thomas Holgate, Mr. H. May (Croydon Gas Company), and Mr. W. J. Liberty (Public Lighting Inspector, City of London), recently paid a visit to H.M. Mint, by the courtesy of the Deputy-Master, and inspected the melting of metal, for the purpose of coinage, by the high-pressure gas-crucibles installed some time ago by the Commercial Gas Company to supersede coke furnaces. After witnessing the various processes, from the melting of bar silver to the testing of the finished coins, the party proceeded to Cannon Street to witness a demonstration of the raising, lowering, and travelling of the public centrally-suspended high-pressure "Keith" gas-lamps. The demonstration was carried out by Mr. Liberty, with the lamps under lighting conditions, and the details of the mechanism were fully explained. Afterwards the party witnessed a similar exhibition with the centrally-suspended arc lamps in Cheapside.

THE NORTH-EAST COAST COAL TRADE.

From our Own Correspondent.

Race-week holidays have been a far more prominent feature during the last week than new business, and the market shows no signs as yet of any recovery. Collieries are working as far as possible on their contract orders, and the merchants who are forced to take out the coal must, in many cases, be making heavy losses. Such offers as do come from abroad are at prices considerably below what the collieries will accept.

July prospects are poor, and much idle time appears probable. The wages ascertainments are not yet published, but wages reductions cannot in any case be sufficient to enable collieries to live at current obtainable prices. As far as can be seen at present, there are no factors in view likely to create any substantial demand, so that, unless anything unforeseen occurs, better times for collieries are likely to be delayed until such time as shortage due to forced idle time makes itself felt.

Better class gas coals are still the only department that shows any sign of firmness. Wear Specials are quoting 23s. 6d. to 24s. f.o.b., and best qualities (Holmside, New Pelton class) hold out for 23s. for forward. Seconds and other qualities are, however, freely offered at 20s. to 20s. 6d.

COAL TRADE IN THE MIDLANDS.

From our Local Correspondent.

The end of June found very few contracts of the new year's supplies uncompleted. Those engineers who waited till midsummer before they applied themselves to serious negotiations did very well—appreciably better than those who deemed it the wiser course to pay a shilling to two shillings advance rather than run the risk of the market hardening against them. Some of the big undertakings were able to get contracts renewed at the old rates; in other cases the advance was quite small. Collieries that refused to abate their terms were outbid for the trade. With few exceptions contracts were made over the twelve months. Tonnages were rather higher in some instances. A notable advance was made in putting business on a more regular footing. Where bargains rested on the basis of a more or less flexible understanding in the past, it has been deemed more satisfactory to have formal contract notes. These notes have now been freed to a very large extent from the special clauses relating to strikes and other contingencies. The rights reserved by the collieries to vary the terms of the contract have not been exercised in practice, and it is considered that, if in the abnormal conditions through which the trade has been passing adherence to the original engagement was possible, it is undesirable to complicate future business with conditions which lose their force through being ignored.

YORKSHIRE AND LANCASHIRE COAL TRADE.

From our Local Correspondent.

Gas coals are not in immediate demand in Yorkshire and Lancashire for prompt delivery, but inquiries are available over twelve months from the beginning of July or August. There is no appreciable difference in the house coal market as compared with last week. Orders are coming through slowly, and are easily executed. Industries appear to be gradually worse in regard to their demands, and prices rule accordingly.

Export continues dull, and the inquiries from the nearer Continental countries indicate prices that are not acceptable to Yorkshire and Lancashire producers at the moment.

Collieries generally are experiencing difficulties in regard to their working hours, many of them being confined to three or four days per week. Prices at Hull at the week-end were: Bunkers—Yorkshire, Derby, and Notts large screened steam, 20s. to 21s., f.o.b. Humber ports. Cargo for export, f.o.b. usual shipping ports—best Yorkshire hards, Association, 24s. 9d.; Derby best hards, 23s. 6d. to 26s.; West Yorkshire Hartleys, 22s. to 24s.; South Yorkshire washed doubles, 22s.; ditto washed singles, 21s.; dry doubles, 16s. 6d. to 17s. 6d.; South Yorkshire washed smalls, 16s.; Derby slack, 1 in., 14s.; South Yorkshire rough slack, 15s.; gas coke, 34s.; foundry furnace coke, 24s. 6d. to 25s. 6d.; washed smithy peas, 23s. 6d. to 28s.; washed steam thirds, 20s. 6d. to 20s. 9d; South Yorkshire washed trebles, 22s. 6d.

Reduction in Price at Blackburn.—At a meeting of the Blackburn Town Council, on June 5, Mr. E. Hamer (Chairman of the Gas Committee) said they were once more able to reduce the price of gas by 3d. per 1000 c.ft., consequent upon a profit of £11,000. In the last five years, £86,000 has been paid out of revenue for new mains.

Gas-Works Under the "Red Flag."—At the Tipperary County Court, the local Gas Company claimed compensation in respect of loss sustained through the gas-works being taken over and worked by men under the "red flag" from March to July, 1922. Mr. P. L. Adams, Manager of the works, stated that when they were taken over he was warned by letter from the Council of the Committee of the Red Flag not to enter the place. At the time there was a stock of 500 tons of coal, and when the intruders left not a lump of coal remained. The control, he understood, was on Soviet lines. During its continuance the military and police barracks, which were in occupation of Republican forces opposed to the Free State Government, were supplied with gas. Free State troops ultimately surrounded the town and took possession of it, shooting down the red flag. Judge Sealy said there could be no doubt that the Company had sustained serious loss, but he had no power to compensate for custom or profit. He awarded £195.

CURRENT SALES OF GAS PRODUCTS.

The London Market for Tar, Tar Products, and Sulphate of Ammonia.

LONDON, *June* 30.

Business in the London tar products market is quiet, as is usual at this time of the year, and prices are therefore nominal. Makers are busy with deliveries of road tar; the authorities taking advantage of the fine weather to push on with their road work.

Tar Products in the Provinces.

June 30.

The market for tar products has been rather quiet throughout the past week. In pitch some sales are reported at slightly lower figures. The market for creosote is on the weak side, with very little fresh business. For crude carbolic some improved prices are reported to have been paid. Little or no business is reported in other articles.

The average values for gas-works products during last week were: Gas-works coal tar, 48s. to 53s. Pitch, East Coast, 58s. to 60s. 6d. f.o.b. West Coast—Manchester, 54s. to 56s. 6d.; Liverpool, 55s. to 57s.; Clyde, 56s. to 58s. Benzole 90 p.c., North, 1s. 5d. to 1s. 6d.; crude 65 p.c. at 120° C., 1s. to 1s. 1d. naked at makers' works; 50-90 p.c., naked, North, 1s. 8d. to 1s. 10d. Toluole, naked, North, 1s. 5d. to 1s. 6d., nominal. Coal tar crude naphtha in bulk, North, 7½d. to 8d. Solvent naphtha, naked, North, 1s. 4d. to 1s. 5d. Heavy naphtha, North, 1s. 2d. to 1s. 3d. Creosote, in bulk, North, liquid, 7d. to 7½d.; salty, 6d. to 6¾d.; Scotland, 6d. to 6¼d. Heavy oils, in bulk, North, 9d. to 9½d. Carbolic acid, 60 p.c., 1s. 9d. to 1s. 11d. prompt. Naphthalene, £15 to £16; salts, £6 to £8, bags included. Anthracene, "A" quality, 4d. per minimum 40 p.c., purely nominal; "B" unsaleable.

Sulphate of Ammonia Prices on the Nitrogen Basis.

The British Sulphate of Ammonia Federation have adopted the nitrogen basis in place of the ammonia basis for future quotations. This will remove the obscurity that has hitherto existed, as is shown in a leaderette in an early part of this issue of the "JOURNAL" [see p. 60]. The announcement of the change is made in their circular as to prices for July and August delivery. The price is £14 per ton for neutral quality in fine friable condition, free from lumps, basis 21·1 p.ct. nitrogen, delivered to consumer's nearest station or wharf in Great Britain, for prompt cash payment, in lots of 4 tons and upwards. Limited quantities of ordinary quality will be available in some districts, and will be sold at 23s. per ton less than the above prices, basis 20·7 p.ct. nitrogen.

Neutral sulphate of ammonia, guaranteed not to contain more than ·025 p.ct. free acid, will be sold on the basis of 21·1 p.ct. nitrogen, with no charge if over 21·1 p.ct., but with an allowance per ton of—

	P.Ct.		P.Ct.
1s. 6d. if the content of nitrogen is under	21·10	but not under	21·00
3s. od. " " " "	21·00	" "	20·90
4s. 6d. " " " "	20·90	" "	20·80
6s. od. " " " "	20·80	" "	20·70
7s. 6d. " " " "	20·70	" "	20·60
9s. od. " " " "	20·60	" "	20·50
10s. 6d. " " " "	20·50	" "	20·40
12s. od. " " " "	20·40	" "	20·30

A further allowance of 9s. 6d. per ton will be made should the content of free acid exceed ·025 p.ct., and an allowance of 9s. 6d. per ton will also be made should any delivery of neutral sulphate not be in fine friable condition free from lumps.

Ordinary sulphate of ammonia will be sold on the basis of 20·7 p.ct. nitrogen, with no charge if over 20·7 p.ct., but with an allowance per ton of—

	P.Ct.		P.Ct.
1s. 6d. if the content of nitrogen is under	20·70	but not under	20·60
3s. od. " " " "	20·60	" "	20·50
4s. 6d. " " " "	20·50	" "	20·40
6s. od. " " " "	20·40	" "	20·30
7s. 6d. " " " "	20·30	" "	20·20
9s. od. " " " "	20·20	" "	20·10
11s. od. " " " "	20·10	" "	20·00
13s. od. " " " "	20·00	" "	19·90
16s. od. " " " "	19·90	" "	19·80
19s. od. " " " "	19·80	" "	19·70
22s. 6d. " " " "	19·70	" "	19·60
26s. od. " " " "	19·60	" "	19·50

The above qualitative deductions apply only to deliveries of 2 cwt. and over.

For each separate delivery of less than 4 tons, whether *ex* works or by rail or water, the following extra charge will be made, even if the total quantity purchased is greater than 4 tons:

2 tons and over, but less than 4 tons,	5s.	per ton over 4 ton price.	
1 ton " " " "	2 tons,	10s. "	"
2 cwt. " " " "	1 ton,	1s. per cwt.	"
1 cwt. " " " "	2 cwt.,	2s. "	"
28 lbs. " " " "	1 cwt.,	3s. "	"
14 lbs. " " " "	28 lbs.,	4s. "	"

To fertilizer manufacturers, agricultural merchants, and co-operative societies registered under the Friendly Societies Acts, or any other Act, a commission of 10s. per ton will be allowed on all deliveries.

Irish Gas Prices.—When the Strabane (Tyrone) Urban Council decided to reduce the price of gas by 9d. per 1000 c.ft., making the total cost 6s. 9d., it was mentioned that in thirty towns in Ireland the price of gas was not below 7s. 6d. per 1000 c.ft.

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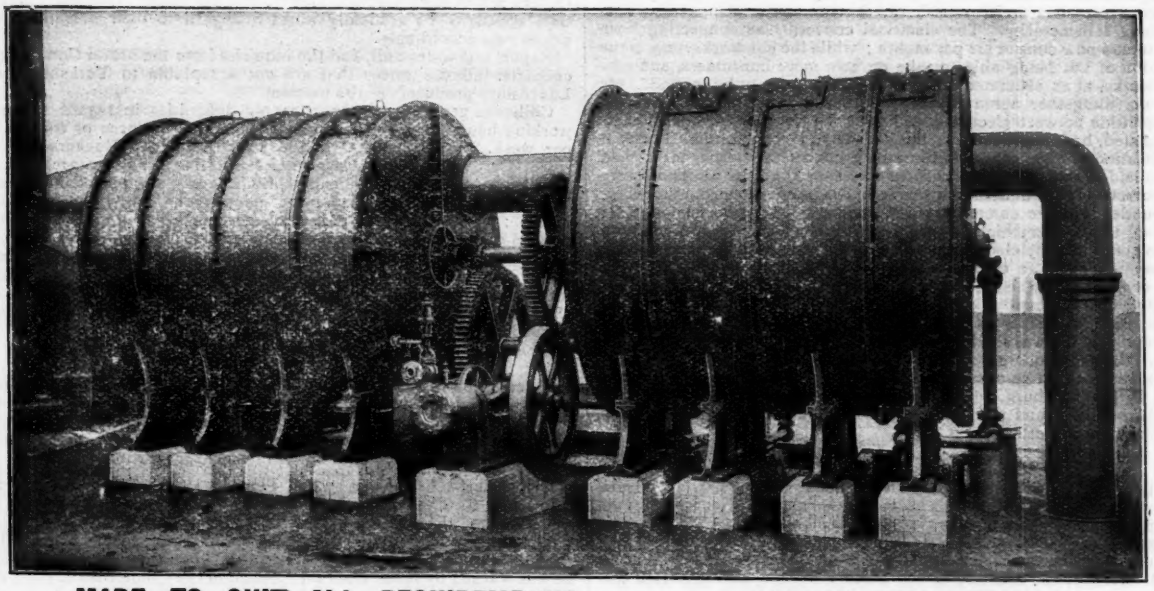

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TRADE NOTES.

Coal Gas Plant for the University of Peking.

The National University of Peking have placed an order with Messrs. Firth Blakeley, Sons & Co., Ltd., Church Fenton, for a complete coal-gas plant, including Blakeley's patent baffle-plate condensers, for the University Chemical Department.

Tully Gas Plant for Belleville.

Messrs. Tully Gas Plants, Ltd., have been commissioned by the Belleville City Council to erect a gas plant capable of producing 45,000 c.ft. of 450 B.Th.U. gas per ton of coal, with an oil consumption of less than 1½ gallons per 1000 c.ft. The Committee who investigated the matter express their complete satisfaction with the plant, and feel assured that the decision arrived at is a wise move.

Keith-Blackman Specialities.

Two new pamphlets are to hand from the James Keith and Blackman Company, Ltd., of No. 27, Farringdon Avenue, London, E.C. One of these illustrates a few typical Keith induced-draught plants, thereby showing the simple character of these installations. If a large chimney already exists, the fan can be employed to augment the natural draught; but for new works the entire draught is provided by the fan, and a short chimney of relatively small diameter employed. Keith induced draught fans can be arranged for any drive—by belt from an existing source of power, or by direct-coupled steam engine or electric motor—and it will usually be found that existing flues can be connected-up to during a week-end, without interfering with the regular working of the boiler plant. The second pamphlet is on the subject of "K-B" patent blowpipes for lamp-blown glassware, &c., for use with both gas and air at 2 to 3 lbs. per sq. in. pressure. These burners have been evolved to meet the demand for a needle-shaped flame of high velocity and high temperature, and work on entirely novel principles. The chief feature of the burners is that a mixture of gas and air is preheated to a high extent by burning a portion of the mixture to heat the remainder. The principle employed enables burners to be constructed in various sizes, giving a wide range of length and size of flame.

Bahia Blanca Gas Company, Ltd.—The Directors will report at the meeting next Wednesday (July 9) that the debit balance of revenue account for 1923 is £3239, and there is an amount of interest on participating debenture stock (unpaid) of £5400. With the debit balance brought forward, there was at Dec. 31 last a total debit balance of £57,363. The quantity of gas sold was practically the same as in the previous year. Recent reports are to the effect that the harvest in the Bahia Blanca region has been abundant; and it is hoped that this, in conjunction with reduced prices, will enable the Company to increase their sales.

Lancaster Corporation Gas-Works.

Councillor Till (the Chairman) drew the attention of the Lancaster Town Council to the satisfactory report of the Gas Engineer (Mr. George Dixon, B.Eng.), showing that the total receipts for the past year were £82,104, and the expenditure £59,164, leaving a gross profit of £22,939, which was reduced by interest and other charges to £11,761. A sum of £4000 was taken for the relief of the rates, and £7761 was placed to reserve—this fund standing at £29,560. Coal cost £26,055, averaging over 21s. 9d. per ton, against 23s 9d. the previous year. Residuals realized £23,306, or 89·5 p.ct. of the total cost of coal. The average price received for gas was 2s. 9·6d. per 1000 c.ft. The net cost of manufacture and distribution was 1s. 3·04d. per 1000 c.ft., and the net profit 9·49d. per 1000 c.ft. Unaccounted-for gas amounted to 6·1 p.ct. The Market Square showrooms continue to do good business, and provide a necessary link between the department and the consumers. The outside shop lighting scheme, put into operation last winter, became exceedingly popular. The old retort-house has proved too small, and the attendant coal and coke handling too costly for it to be maintained in working order. The Committee are therefore faced with the necessity for building a new retort-house, which will cost approximately £60,000.

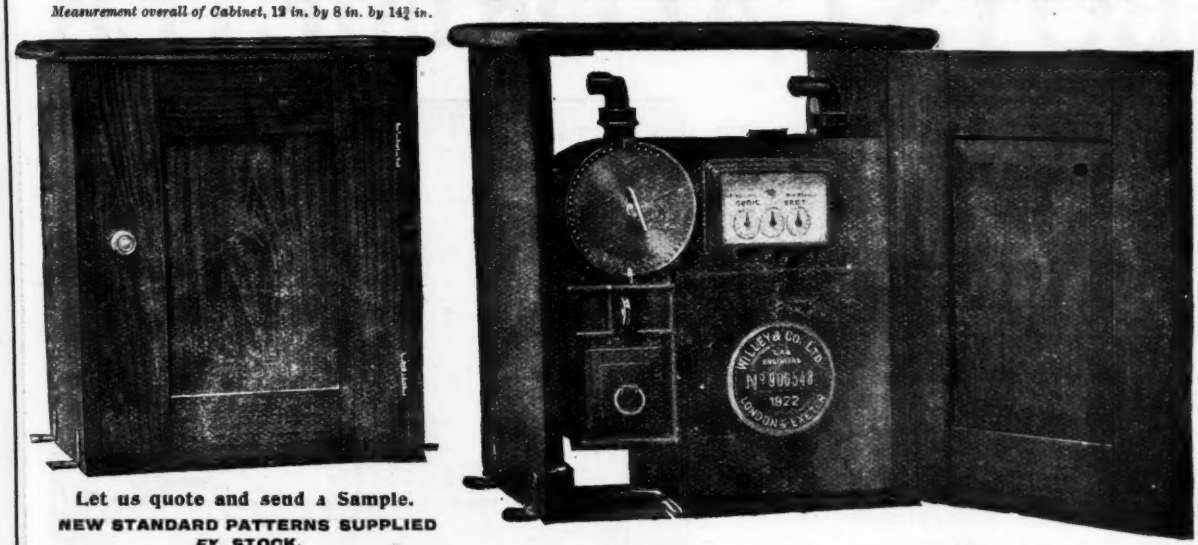
Croydon Co-Partnership Committee.—The report of the Croydon Gas Company Co-Partnership Committee for the year ended March 31 last shows that up to that date from the inception of the scheme in 1909 1423 co-partnership agreements had been entered into, and 621 terminated, leaving 812 in force. The total holdings acquired to date by co-partners through the scheme figure in the accounts at £16,820. The bonus is at the rate of 6½ p.ct. (as against 6 p ct. for the previous year), being the average rate at which dividend was paid on the sliding-scale stock of the Company for 1923.

Portsmouth Gas-Works Extensions.—The Portsea Island Gas Company, who serve the town of Portsmouth and certain outlying districts, have entered upon contracts to the extent of over £100,000, with a view to coping with the increased demand upon their resources. At their main works at Hilsea a holder with a capacity of 2 million c.ft. is in course of construction, and it is proposed to extend the workshops, stores, and meter-house, and to provide a new dining hall and other accommodation for the men. Half of the horizontal retorts are being rebuilt on modern lines, while the installation of vertical retorts is to be duplicated. Waste-heat boilers are to be installed, and other new plant is to be laid down. This part of the work alone, it is estimated, will cost £90,000. Considerable extensions are also being carried out at the Company's stations at Flathouse and Rudmore, while the distribution department is receiving attention with the object of further improving the pressure and regulating the supply throughout the district. New mains are being laid, and plans have been approved for showrooms in various parts of the area.

THE GAS FIRE METER.

A Boon to Hotel and Boarding House Proprietors. **Neat and Compact.**

Measurement overall of Cabinet, 12 in. by 8 in. by 14¾ in.



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North-Eastern Showrooms: Commercial Street, DARLINGTON.

End of Nottingham Plumbers' Strike.—There was a complete collapse on Monday of last week of a general strike of plumbers at Nottingham, when the men who had been out for several weeks in support of claims which had been advanced by stove and meter fixers in the employ of the Gas Committee of the Nottingham Corporation returned to work. The stove and meter fixers had originally formulated demands that they should, in regard to rates of remuneration, be treated by the municipal authorities as being upon a footing as skilled plumbers. In opposition to this contention, the Committee were supported, in the general interest of the gas industry, by the National Joint Industrial Council; but in the fruitless endeavour to alter a decision which was based upon eminently practical grounds, Nottingham plumbers sought to elaborate the trouble by co-operating with the malcontents. Now, in view of the firm attitude which had been maintained, they have submitted to the inevitable, and resumed work. Their obduracy has, however, occasioned no small amount of dislocation to building and other operations. Meanwhile, most of those who had been the original cause of the upset had found that their services were no longer needed by the Gas Committee, who have thus given a severe lesson.

Hinckley Gas Profits.—The Manager of the Hinckley Urban Council gas undertaking (Mr. Fred Lee) presented his annual report to the Council last week. He stated that capital and loan account showed a total expenditure on works, mains, &c., of £111,289, and of this amount £43,420 had been repaid. From profits, £31,841 had been transferred, leaving the outstanding debt £36,529. During the year, £13,400 had been borrowed for the vertical retorts. The year's instalment to the sinking fund account was £2345, and loans amounting to £2653 had been repaid. Coal and oil had cost £15,031, compared with £15,545 last year—a decrease of £514. Gas making was started in the new retorts at the end of September, and the result of six months' working was very satisfactory. The gross profit was £8485, compared with £6816 last year; being an increase of £1669. The net profit was £4759; being £598 more than last year. The gas made was 160,220,000 c.ft., and the gas sold 155,270,400 c.ft., which showed an increase of 8·5 p.ct. over last year. The gas unaccounted-for was 2·23 p.ct., compared with 2·21 p.ct. last year. Mr. Bott, Chairman of the Gas Committee, moved the adoption of the report, which also recommended the following reductions in the price of gas: For cooking and lighting, from 3s. 8d. to 3s. 4d. net; heating, from 3s. 1d. to 3s., and the abolition of meter rents; power from 3s. 1d. to 2s. 9d. net. The Committee also recommended that a rebate of 6d. per 1000 c.ft. be allowed to all consumers of gas for power for any increased quantity used over the amount last year. They hoped by this means to encourage the use of gas for this purpose. He paid a tribute to the good work of Mr. F. Lee, the Manager, and further moved that the best thanks of the Council be tendered to him for the very able manner in which he had carried out his work during the past year. The report was adopted.

Bournemouth Company's New Capital.—By instruction of the Board, Messrs. A. & W. Richards are offering for sale by tender 7000 £10 new ordinary shares in the Bournemouth Gas and Water Company, on terms which are intimated in our advertisement columns. Increased demands for gas and water necessitate this new issue of shares, tenders for which must be forwarded to No. 37, Walbrook, by the 9th inst.

Hereford Gas Prices.—The Gas Committee of the Hereford City Council recommended a reduction, as from June 24, in the discount of 3d. per 1000 c.ft. for prompt payment to 2d. per 1000 c.ft., with a corresponding reduction in the discount paid to slot-meter consumers. Alderman Symonds, in moving the adoption of the report, said that the Committee regretted having to take this step. They had been too generous in the past in their concessions to consumers, and the accounts for last year were not satisfactory. The motion was adopted.

The Directors of Messrs. Gibbons (Dudley), Ltd., have declared interim dividends on the preference and ordinary shares of 7 p.ct. per annum, free of income-tax, for the six months ended June 30.

Towards the end of last week, considerable damage by fire was caused to the packing department in Fitzroy Court, Euston Road, of Messrs. Ewart and Son, Ltd. The building was partially burnt out, and many cases of geysers suffered.

For the £4500 of 6 p.ct. redeemable debenture stock in the Crowborough District Gas and Electricity Company which Messrs. A. & W. Richards offered on behalf of the Directors, the applications covered the amount several times over.

Quotations in accordance with the London County Council's specification have been accepted for improving the gas lighting at a number of schools. The Education Committee have also authorized the invitation of quotations with a similar object in connection with twenty-five other schools.

The Hereford Gas Committee are recommending to the City Council that the price of gas be increased by 3d. per 1000 c.ft. (from 4s. to 4s. 3d.) as from June 24. The reduction in discount to 2d. per 1000 c.ft. passed by the Council at the June meeting will be advanced to the old rate of 3d. per 1000 c.ft. for prompt payment. A corresponding increase will be made in the price of gas to consumers on the prepayment system.

Having regard to the impending reduction in the price of gas at Chorley, it is interesting to recall that the first gas-works in the town were erected by private enterprise, and for private use only. They were built to illuminate the manufactory of Mr. Thomas Lightoller, of Standish Street. The inhabitants had to wait until 1819 for the first public works for gas making, and then, again, a private company made the move. In 1833 the works were extended.

GAS REGULATION ACT, 1920.

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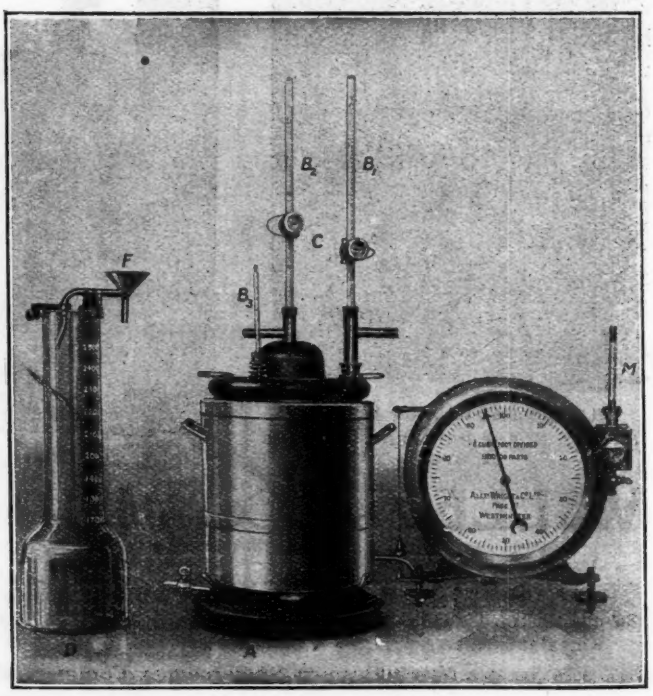

STOCK MARKET REPORT.

THE reparations question continues to figure prominently in the financial position, and considerable discussion has taken place with regard to the famous meeting between the English and French Premiers. A more favourable view of the outlook is taken on the Continent than in this country; but this is probably due to the more amenable attitude of Germany. There was little sign of any expansion of business on the Exchange, but the general tone was satisfactory, especially as regards Home Railway stocks, Foreign Government bonds, and Argentine Railway stocks. The outstanding feature of the Foreign Government Market was the revival of activity in German bonds on reported buying from Berlin. The prospect of dearer money depressed gilt-edged stocks, the prices of which are influenced almost solely by the value of money.

In the Industrial Market Courtaulds pleasant surprise of a bonus of two in three of new 5 p.ct. preference shares brought about considerable business in the shares, which rose rapidly to 70s., finally closing on Friday, on profit taking, at 67s. There has been a demand for Tobacco shares, both Imperial and British American showing substantial improvement on the week. In spite of rumours of the good business secured at the Wembley Exhibition, Iron and Steel remained quiet and irregular. Gas stocks were normal; and it will be seen that the changes in the quotations were mainly due to interest payments.

The following transactions were recorded during the week:

On Monday, Aldershot 4 p.ct. preference 72, Brentford "A" 101½, Commercial 4 p.ct. 91½, 3½ p.ct. 91, 3 p.ct debenture 57½ *ex* div., European 7, Gas Light and Coke 92, 92½, 92½, 92⅝, 92⅞, 3½ p.ct. maximum 64, 4 p.ct. preference 81, 81½, 3 p.ct. debenture 63 *ex* div., Hastings and St. Leonards 3½ p.ct. 78½, Imperial Continental 152, 152½, 152⅝, 153, Newcastle 3½ p.ct. 84, Primitiva 7s., 4 p.ct. (Buenos Ayres) debenture 57½, South Metropolitan 98⅝, 99, 99½. Supplementary prices, Southend-on-Sea 5 p.ct. 86½, 87.

On Tuesday, Alliance and Dublin 64½, Commercial 4 p.ct. 92½, Continental Union 28½, Gas Light and Coke 92, 92⅛, 92⅜, 4 p.ct. preference 81, 81⅛, 3 p.ct. debenture 61½, 62, 62⅛, *ex* div., Imperial Continental 151½, 153½, Lea Bridge 5 p.ct. 98, Primitiva (Buenos Ayres) debenture 57½, South Metropolitan 98⅛, 99½, 99⅝, 100, 3 p.ct. debenture 60½, 61½.

On Wednesday, Brentford "A" 102½, Croydon sliding-scale 103½, 103⅜, Gas Light and Coke 92, 92⅛, 3½ p.ct. maximum 63½, 4 p.ct. preference 81, Imperial Continental 152, 152½, Liverpool 7 p.ct. preference 105½, Montevideo 55, Primitiva 7s., 7s. 6d., South Metropolitan 99½, 99⅝, 99⅞, 99⅞, 100, 3 p.ct. debenture 60½, 62, South Suburban 5 p.ct. 103½, 104½, 105, Tottenham "B" 102, 102½.

On Thursday, Brentford "A" 102½, Gas Light and Coke 91⅞, 92, 92⅛, 92¼, 92⅜, 92⅝, 4 p.ct. preference 82; Imperial Continental 153, 153½, South Metropolitan 99½, 100, South Suburban 105. Supplementary prices, Brighton and Hove 6 p.ct. "B" preference 107½, Uxbridge 5 p.ct. 96½, Walton-on-Thames 10 p.ct maximum "A" 14⅛, 7 p.ct. maximum "B" 10 1/16, 10 3/16.

On Friday, Alliance and Dublin 64, 64⅛, 64 11/16, Bombay 5⅜, British 117½, 118¾, Continental Union 29, Gas Light and Coke 91⅞, 92, Imperial Continental 153½, Primitiva 7s., South Metropolitan 100, South Suburban 104½, Southampton 86.

As expected, Treasury Bills sold by tender were allotted at an appreciably higher discount rate; the average being £3 2s. 9·42d. p.ct., which is the highest rate for several months. The recommendation from an eminent financial authority of a higher bank rate did not materialize last week; but it is expected that an increase therein will shortly be made. The argument is made that the improvement in the American exchange compared with a year ago alone justifies a higher rate. Large sums were borrowed during the week from the Bank of England in preparation for the window-dressing demands at the end of the half-year.

Very quiet conditions prevailed on the Foreign Exchange Market. The feature of the week was the steadiness of the dollar-sterling, which closed at 4.32 5/16. French and Belgian francs fell away slightly, and Dutch florins and Italian lire also closed at prices more in favour of this country.

There was a rally in the price of bar silver at the end of the week, due to some "bear" covering from China, and the price closed at 34 3/8d. per oz.

The Bank rate is 4 p.ct., to which it was raised from 3 p.ct. on July 5 last. Bankers' deposit rates are 2 p.ct. The deposit rates of the discount houses are 2 p.ct. at call and 2½ p.ct. at notice.

Issue.	Share.	When ex-Dividend.	Dividends. Prev. Hf.Yr.	Dividends. Last Hf. Yr.	NAME.	Quotations. June 27.	Rise + or Fall − on Week.	Transactions Lowest and Highest Prices.
£			% p.a.	% p.a.				
131,978	Stk.	Feb. 7	5	5	Aldershot 5 p.c. max. C.	81—84	+2	..
235,492	,,	,,	4	4	Do. 4 p.c. Pref.	70—73	..	72
1,551,868	,,	Apr. 3	5½	6	Alliance & Dublin Ord.	63—68	..	64—64 11/16
374,000	,,	Jan. 10	4	4	Do. 4 p.c. Deb.	60—65	..	..
280,000	5	May 22	8	8	Bombay, Ltd.	5—5⅜	..	5⅜
100,000	10	Mar. 6	8½	8½	Bournemouth 5 p.c.	12½—13½	..	..
383,110	10	,,	7	7	Do. B 7 p.c.	12—13	..	..
150,000	10	,,	6	6	Do. Pref. 6 p.c.	11—12	..	..
50,000	Stk.	June 26	3	3	Do. 3 p.c. Deb.	54—59*	−1	..
162,025	,,	,,	4	4	Do. 4 p.c. Deb.	74—79*	−1	..
992,045	,,	Feb. 21	6 1/16	6 1/16	Brentford A Con.	98—103	..	101½—102½
990,500	,,	,,	6⅛	6½	Do. B New	98—103	..	..
76,000	,,	,,	5	5	Do. 5 p.c. Pref.	89—94	..	..
306,690	,,	June 12	4	4	Do. 4 p.c. Deb.	75—80	..	..
181,337	,,	,,	—	6	Do. 6 p.c. Rich. Red. Deb.	98—103	..	..
214,740	,,	Mar. 6	11	11½	Brighton & Hove Orig.	170—175	..	..
244,200	,,	,,	8	8½	Do. A Ord.	125—128	..	..
1,287,500	,,	Feb. 21	5	5	Bristol 5 p.c. max.	92—93*a*	..	..
855,000	,,	Mar. 20	—	7	British Ord.	117—122	..	117½—118⅝
100,000	,,	June 26	7	7	Do. 7 p.c. Pref.	118—123*	−2	..
120,000	,,	,,	4	4	Do. 4 p.c. Red. Deb.	72—77*	−1	..
100,000	10	May 22	6	8	Cape Town, Ltd.	6½—7½	..	..
100,000	10	Apr. 24	4½	4½	Do. 4½ p.c. Pref.	6—7	..	..
150,000	Stk.	June 26	4½	4½	Do. 4½ p.c. Deb.	71—76*	−2	..
626,860	,,	Feb. 21	6	6	Cardiff Con. Ord.	99—102	..	..
237,860	,,	June 26	7½	7½	Do. 7½ p.c. Red. Deb.	102—107*	−3	..
157,150	,,	Mar. 6	5	6½	Chester 5 p.c. Ord.	88—93*b*	..	..
1,513,280	,,	,,	6	6	Commercial 4 p.c. Cap.	90—95	..	91½—92½
560,000	,,	,,	6	6	Do. 3½ p.c. Cap.	90—95	..	91
475,000	,,	June 12	3	3	Do. 3 p.c. Deb.	56—59	..	57½
800,000	,,	14 Jan. 15	—	—	Continental Union, Ltd.	27—32	..	28½—29
200,000	,,	June 12	7	7	Do. 7 p.c. Pref.	75—80	..	..
660,000	,,	Mar. 6	6½	6½	Croydon sliding scale	101—104	..	103½—103½
284,975	,,	,,	5	5	Do. max. div.	84—87	..	..
492,270	,,	Feb. 21	3	4½	Derby Con.	108—110*c*	..	..
55,000	,,	Jan. 12	4	4	Do. Deb.	74—76*c*	..	..
209,000	,,	Apr. 3	5	5	East Hull 5 p.c. max.	..	..	..
1,002,180	10	Jan. 24	3	2	European, Ltd.	6½—7½	..	7
16,503,045	Stk.	Feb. 7	5⅜	5⅜	Gas Light & Coke 4 p.c. Ord.	91—93	−1	91½—92½
2,600,000	,,	,,	3½	3½	Do. 3½ p.c. max.	62—65	..	63½—64
4,062,235	,,	,,	4	4	Do. 4 p.c. Con. Pref.	80—83	..	81—81½
4,761,930	,,	June 12	3	3	Do. 3 p.c. Con. Deb.	60—63	..	61½—63
130,000	,,	Dec. 11	10	10	Do. 10 p.c. Bonds	..	..	..
42,000	,,	—	7½	7½	Do. 7½ p.c. Ilford Deb.	..	..	..
82,500	,,	Mar. 20	6⅝	6⅝	Hastings & St. L. 5 p.c. Conv.	91—96	..	..
258,740	,,	,,	5⅛	5⅛	Do. 3½ p.c. Conv.	76—81	..	78½
70,000	10	May 8	10	10	Hongkong & China, Ltd.	16—17	..	..
86,600	Stk.	Mar. 6	9½	10	Hornsey 7 p.c.	143—148	..	..
1,976,000	,,	May 22	10	30	Imperial Continental Cap.	150—155	..	151½—153½
263,950	,,	Feb. 7	3⅛	3⅛	Do. 3½ p.c. Red. Deb.	69—72	..	..
235,242	,,	Mar. 6	6⅜	6⅜	Lea Bridge 5 p.c. Ord.	95—100	..	98
2,127,340	,,	Feb. 21	5⅛	5⅛	Liverpool 5 p.c. Ord.	91½—92½*b*	..	..
600,000	,,	Mar. 20	7	7	Do. 7 p.c. Red. Pref.	103—106*b*	..	105½—106
165,736	,,	Feb. 21	9	8	Maidstone 5 p.c. Cap.	124—129	..	..
63,480	,,	June 26	3	3	Do. 3 p.c. Deb.	53—58*	−1	..
73,000	5	,,	7	5	Malta & Mediterranean	3½—3¾*	−¼	..
341,920	Stk.	June 12	4	4	Montevideo, Ltd.	52—57	..	55
1,875,892	,,	Mar. 6	4¼	5½	Newcastle & Gateshead Con.	85½—85¾*d*	+½	84—85½
250,266	,,	,,	4	4	Do. 4 p.c. Pref.	75—77*d*	+1	..
529,705	,,	June 26	3½	3½	Do. 3½ p.c. Deb.	70—72*d*	−1	..
15,000	10	Mar. 6	11	11	North Middlesex 10 p.c.	16—17	..	..
73,940	10	,,	7 7/16	7 7/16	Do. 7 p.c.	11¾—12¼	..	..
300,000	Stk.	May 8	9	7	Oriental, Ltd.	98—101	..	..
138,120	,,	June 26	7¼	7½	Plym'th & Ston'house 5 p.c.	112—117*	−3	..
60,000	50	Mar. 6	13	13	Portsea Island B	102—105	..	..
100,000	50	,,	12	12	Do. C	98—103	..	..
2,289,909	1	—	—	—	Primitiva Ord.	1/16—1/8	..	7/0—7/6
341,400	100	June 2	4	4	Do. 4 p.c. Red. Deb.	69—74	..	..
600,000	Stk.	Jan. 24	4	4	Do. 4 p.c. Red. Deb. 1911	54—57	..	..
220,355	,,	June 26	4	4	Do. B. Aires 4 p.c. Rd. Db.	54—57*	−1	..
321,670	,,	,,	4	4	Do. R'r P'te 4 p.c. Rd. Db.	54—57*	−1	..
150,000	10	Mar. 20	6	6	San Paulo 6 p.c. Pref.	6½—7	..	..
125,000	50	Jan. 2	5	5	Do. 5 p.c. Red. Deb.	39—41	..	..
270,000	Stk.	Mar. 20	5	5/8/4	Sheffield A	100—101*e*	−⅛	..
419,968	,,	,,	5	5/8/4	Do. B	100—101*e*	−⅛	..
1,047,000	,,	,,	5	5/8/4	Do. C	99—101*e*	−⅛	99½
90,000	10	June 12	6	8	South African	7—9	..	..
6,609,895	Stk.	Feb 21	5	6½	South Met. Ord.	98½—100½	..	98½—100
102,580	,,	Jan. 10	5	5	Do. Red Pref.	98—100	..	..
1,895,445	,,	,,	3	3	Do. 3 p.c. Deb.	59—62	+1	60½—62
734,000	,,	Mar. 6	6½	6½	Do. 6½ p.c. Red. Deb.	103—105	..	..
91,500	,,	,,	8½	8½	South Shields Con.	136—138*d*	..	..
1,087,795	,,	Feb. 21	6	6½	South Suburban Ord. 5 p.c.	101—106	+1	103½—105
368,837	,,	June 26	5	5	Do. 5 p.c. Deb.	93—98*	−2	..
647,740	,,	May 8	6	5	South'mpt'n Ord. 5 p.c. max.	84—87	..	86
121,275	,,	June 26	4	4	Do. 4 p.c. Deb.	71—78*	−1	..
250,000	,,	Mar. 6	7	7	Swansea 7 p.c. Red. Pref.	104—106	..	..
200,000	,,	June 26	6½	6½	Do. 6½ p.c. Red. Deb.	101—103*	−2	..
120,000	,,	Feb. 21	8	8	Tottenham District A 5 p.c.	119—124	..	..
582,275	,,	,,	6½	6½	Do. B 3½ p.c.	100—103	..	102—102½
181,255	,,	June 12	4	4	Do. 4 p.c. Deb.	76—80	..	..
258,251	,,	Mar. 20	5	7/14/4	Tynemouth Con. and New	87—89*d*	..	..
					Wandsworth, Wimbledon, and Epsom—			
30,000	,,	Mar. 6	9	9½	Wandsworth A 5 p.c.	132—137	..	..
255,636	,,	,,	7½	7½	Do. B 3½ p.ct.	110—113	..	..
108,075	,,	,,	6 5/16	6/7/9	Do. C	96—101	..	..
240,865	,,	,,	6 5/16	6/7/9	New Ordinary	..	..	..
352,000	,,	,,	7⅛	7⅛	Wimbledon 5 p.ct.	108—113	..	..
98,080	,,	,,	7⅛	7⅛	Epsom 5 p.ct.	115—120	..	..
88,416	,,	June 26	3	3	3 p.c. Deb.	55—60*	−1	..

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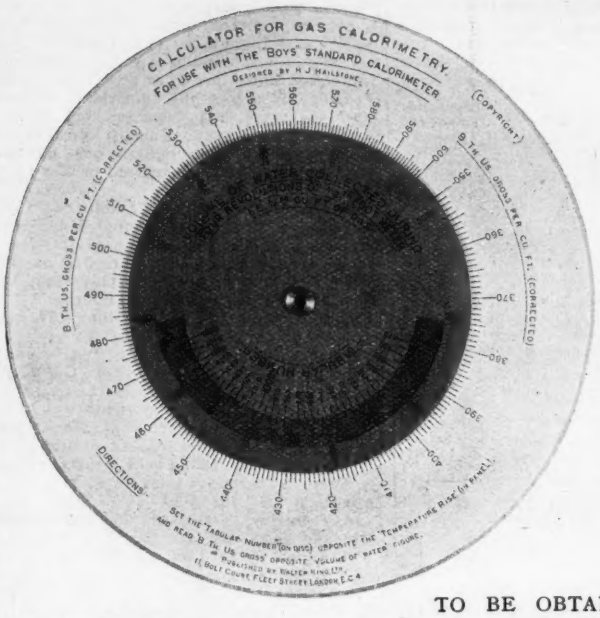
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